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SOME ASPECTS OF THE ECOLOGY AND ENVIRONMENT OF THE SLAVE RIVER DELTA, N.W.T. AND SOME IMPLICATIONS OF UPSTREAM IMPOUNDMENT

by

© MICHAEL CRAWFORD ENGLISH

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Some aspects of the ecology and environment of the Slave River Delta, N.W.T. and some implications of upstream impoundment" submitted by Michael Crawford English in partial fulfilment of the requirements for the degree of Master of Science.

An aerial oblique photograph of the Slave River Delta, facing west overlooking Great Slave Lake.

Courtesy, L. Kershaw.

To my parents and sister Jennifer

ABSTRACT

The Slave River Delta is located at the mouth of the Slave River, 61°13' N, 113°38' W, on the south shore of Great Slave Lake in the Northwest Territories. The 200 km^2 delta is classified as a critical northern wetland by the Mackenzie Valley Intergovernmental Liaison Committee as it provides feeding, staging and breeding habitats for large numbers of waterfowl, muskrat and other species of wildlife. Residents of nearby Fort Resolution depend upon the wildlife resources of the delta for a substantial portion of their food and income.

The continued progradation of the delta into Great Slave Lake results in the formation of new cleavage bars and levees, and the depressions between them support highly productive growths of aquatic and emergent vegetation. Genesis of cleavage bars and interlevee depressions and maintainance of a productive plant cover are a direct product of the natural river regime - periodic flooding and its accompanying sediment load.

Annual spring flooding, enhanced during certain years by ice damming in the distributary channels, is the chief factor responsible for the successional status and microclimate of the delta's vegetation. Infrequent flooding of the elevated apex zone has resulted in the development of a climax *Picea* assemblage and a substantial bryophyte ground cover which reduces soil temperatures and promotes the formation and maintenance of permafrost. The mid delta zone frequently experiences flooding and sedimentation which discourage the development of a bryophyte cover. Flooding and sedimentation also discourage the

germination of *Picea glauca* which results in a *Populus* stage.

The proposed impoundment of the Slave River upstream from the delta for hydroelectric power could negatively affect the ecology of the Slave Delta. The frequency, height, and duration of spring flooding on the delta islands will be reduced as the reservoir volume is depleted after winter high energy demand. The reservoir will trap a large percentage of the bedload and most of the suspended sediment. The developing cleavage bars rely primarily upon bedload and the coarse fraction of the suspended sediment load for their development. Future progradation of the delta will be greatly reduced after the incoming sediment has settled out in the upstream reservoir.

Bryophytes will soon invade the mid portions of the delta and provide conditions conducive to the formation and perpetuation of permafrost. At this time the edaphic climax stage of Decadent *Populus* will be invaded by *Picea glauca* since germination of this species will no longer be retarded by flooding and sedimentation.

Eventually, because the delta can no longer expand at its present rate (due to sediment shortage) and plant succession proceeds to a climax *Picea* stage, habitat modification will result in a reduction of the delta's wildlife. This in turn could have detrimental economic effects upon the people of Fort Resolution.

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CHAPTER ONE

INTRODUCTION

1.1 Thesis outline

This thesis is divided into 6 chapters: Introduction, Study area, Methods, Processes, Vegetation , and Implications of upstream hydroelectric development on the Slave River Delta.

The Introduction chapter defines the problem of upstream hydroelectric development and an hypothesis is presented concerning the effects that development have upon the environment and ecology of the delta. The purpose of the study is stated and a justification of the study is presented. A literature review of recent and related studies of the processes causing delta formation is given and the extent to which man has interfered with northern wetlands by hydroelectric development is stated.

Chapter 2, the Study area, introduces the Slave River Delta, describing its areal extent, geological history, climate, and vegetation, and illustrates the Peace River-Athabasca River-Lake Athabasca hydrological system which is responsible for the regime of the Slave River.

Chapter 3, Methodology, describes the three phases of the study: pre-field season, field season and post-field season work. The pre-field season consisted of air photo interpretation and construction of a preliminary vegetation map. Section 3.2 describes the manner in which the fieldwork was undertaken and methods by which it was accom-

plished. The post-field season included laboratory work on soils, plant species identification and construction of the final vegetation map.

Chapter 4 describes the major environmental processes at work on the Slave River Delta and Chapter 5 describes the plant assemblages in successional sequence.

The final chapter investigates the possible consequences of upstream hydroelectric development upon the environment and ecology of the Slave Delta.

1.2 Introduction

In recent years northern wetlands, particularly the Peace-Athabasca Delta and the Mackenzie Delta, have been the subject of increasing biophysical investigation. Some examples of studies on the Mackenzie River Delta are Mackay (1956, 1963, 1974), Gill (1971, 1972, 1973, 1974, 1977, 1978), Lambert (1972), MacKay and Mackay (1972), Smith (1972), and Peterson (1977). The Peace-Athabasca Delta has been investigated by Card and Yaremko (1970), Kellerhals (1970), Dirschl (1971, 1973), Fuller and LaRoi (1971), Nieman and Dirschl (1971), Reinelt *et al.* (1971), Hennan (1972), Surrendi and Jorgenson (1972), Doherty and LaRoi (1973), Townsend (1973) and Cordes and Strong (1976). Regulation of the Peace River by the W.A.C. Bennett dam since 1968 resulted in significant changes in the ecology of the Peace-Athabasca Delta (as shown by Reinelt *et al.*, 1971). Similar changes may occur on the Slave River Delta if a proposal by Calgary Power is approved to build a hydroelectric dam on the Slave River near Fort Smith, N.W.T.

This thesis deals with ecological aspects of the Slave River Delta, a small but biologically important wetland, located at the mouth of the Slave River on the south shore of Great Slave Lake, 61°13' N, 113°38' W.

The only previous investigations directly applicable to the ecology of this delta were carried out during 1949 on muskrat ecology (Law, 1950) and during the ice-free months of 1971 on soil morphology (Day, 1972). Law's unpublished report focused chiefly on the habitat used by muskrat (*Ondatra zibethicus spatulata*). This included qualitative observations on the composition of plant communities inhabiting the littoral zones along several active distributaries in the delta. Law also sketched the geomorphological change which occurred between 1942 and 1949 based upon aerial photographs (1942) and field observation. A similar collection of maps depicting geomorphological change between 1922 and 1977 is presented in this thesis. Investigations by Day (1972) resulted in a soil map of the delta. Some qualitative work relating plant species composition to soil type was also reported by Day.

1.3 Purpose

The purpose of this project is to evaluate the factors governing the ecology of the wetland marshes of the outer delta and the successional patterns of vegetation assemblages in other portions of the delta. Geomorphological processes such as channel closure, point bar development and cleavage bar development are discussed. Implications of flooding and sedimentation on the delta are discussed and relationships are drawn between flooding frequency and the vegetation assem-

blages inhabiting certain portions of the delta. The relationship between bryophyte distribution and depth to soil frost is investigated.

Finally, this project assesses the potential short- and long-range effects of a regulated water regime on the Slave River Delta, including the implications of a greatly reduced sediment load in the river water discharging from the dam.

1.4 Hypothesis

In view of other studies on the actual and theoretical downstream effects of hydroelectrical installations (Day, 1921; Dirschl, 1971; Reinelt *et al.*, 1971; Fraser, 1972; Haig-Brown, 1972; Armstrong, 1973; Gill, 1973; Jovanovic, 1973; Kellerhals and Gill, 1973; Kerr, 1973; Phelines *et al.*, 1973; Ruxton and Smith, 1973; Green, 1974; Gill and Cooke, 1974; Ross and Marts, 1975; Gill, 1978), I feel that if the Slave River is dammed and its natural flow regime sufficiently altered, the ecology of the Slave River Delta will be substantially degraded.

The initial impoundment period will substantially reduce downstream river levels, and if this period is sufficiently long, successional trends in the emergent vegetation marshes of the outer delta may be altered. After impoundment is complete the seasonal flux of discharge and sediment load will be determined by plant operating strategy. Regardless of the type of dam installed, regulation will reduce downstream flood levels and the amount of sediment carried to the delta. The productivity of this delta, as with all deltas, depends upon annual flooding and sedimentation to maintain vegetation in a successional stage. Successional vegetation is important as it

provides the main food base for waterfowl and aquatic mammals as well as many terrestrial species. Without the annual growth of successional vegetation, it is therefore hypothesized that the trophic levels on the delta would be degraded and vital niches would be destroyed.

1.5 Justification of study

Harmonious balance between hydroelectric feasibility studies and investigation of the downstream impacts of such developments on wetland environments has not yet been achieved in northern Canada. Geen (1974:925) indicated that there is a paucity of ecological environmental impact assessments of the effect of hydroelectric facilities in the Northwest Territories:

> "... there have been no detailed assessments of the ecological effects of hydroelectric developments in the Northwest Territories, although the consequences of several projects in the planning stage are being considered. Careful evaluation of the effects of any of these developments would be desirable, particularly as the frequency of these hydroelectric developments will likely increase, and as the biology of many important aquatic species in these arctic waters is poorly understood."

The Northern Canada Power Commission (N.C.P.C.) has conducted reconnaissance studies on most northern river systems to locate sites for possible hydroelectric dams. However, studies of the effects of hydro installations on downstream wetland environments are still in their infancy. The only detailed studies on the downstream effects of river regulation have been conducted after the dam has been installed (Reinelt *et al.*, 1971; Peace-Athabasca Delta Project Group, 1973), or after work on the project has begun, such as the James Bay hydroelec-

tric project (Richardson, 1972; Taylor *et al.*, 1972; Glooschenko, 1972; Gill and Cooke, 1974).

In February 1972, the Northern Inland Waters Act (Canada 1972) was approved by the Federal Government. This act requires that before any development occurs on a northern water system an environmental impact study has to be completed and public hearings have to be held. The onus for the environmental impact statement is on the developers and the sponsoring government agency (Rempel, Pers. Comm., 1977). N.C.P.C. has evaluated the Mountain Rapids site on the Slave River as being suitable for a hydroelectric dam. Further study by Montreal Engineering in 1971 and 1977 for Calgary Power Ltd., the prospective developers, has resulted in three viable proposals to dam the Slave, one of which would be implemented if the Federal Government agrees to construction. Two of these proposals are large enough to back the reservoir into the Peace-Athabasca Delta during spring runoff.

The degree of change to downstream wetland areas is a function of the impoundment size and what is termed plant operating strategy. The plant operating strategy is simply the amount of discharge allowed through the turbines which is dependent upon the demands of the market to which the power is sold. If the power is sold to Edmonton, or any large urban centre, power demand will be at a maximum during winter months. Plant operating strategy would thus dictate maintenance of high water levels in the reservoir during summer, so that peak power production could be maintained through the winter.

The two smaller proposals are run of the river operations, where

downstream disturbance would be less than the two larger proposals. However, the construction of the larger facilities would cost significantly less per kilowatt hour than the smaller proposals (Table 1.1). Increased uranium development in northwestern Saskatchewan and expanding development of the oil sands deposits of northeast Alberta necessitates a larger source of dependable power. Construction of the Alcan natural gas pipeline, coupled with the service industry growth needed to build the line, will place extra demand on existing power sources. Feasibility studies have been initiated to determine alternate energy supplies for these imminent increases in energy demand (Meeking, Pers. Comm., 1977), and it is clear that a hydro installation on the Slave River has some priorities as a potential supplier of this energy.

Regardless of dam size, regulation of the Slave River will affect the natural regime of the wetland areas downstream, particularly the active delta of the Slave River.

1.5.1 Biological and economic significance of the delta

The Slave Delta is least known of the major northern flood plains. Remote and comparatively small in size, it has previously been overlooked without recognition of its biological importance. During the ice free months the delta provides feeding, staging and breeding grounds for between 40,000 and 200,000 waterfowl (Smith *et al.*, 1964), as three of the four major continental flyways cross over the delta. The large range in waterfowl numbers is a direct function of the area of available wetland on the prairies to the south; when the prairies are dry waterfowl move to northern wetlands such as the

Table[1] 1.1: Slave River hydroelectric development. Comparison of plant operating strategies at Mountain Rapids (Slave River).

Variation	Range in headpond elevation (m a.s.l.)	Total[a] project cost (1977 $) x 10^6	Maximum capacity delivered Mw	Unit cost of capacity ($ Kw)	Average energy delivered Gwh/year[2]	mean Mw	Unit cost of energy $/average Kw
1	201.7	1098	1152	953	6457	737	1490
2	201.8-206.9	1154	1363	847	6916	789	1463
3	208.2-210.1	1194	1487	803	8123	929	1288

a) Includes transmission cost.

1 Montreal Engineering 1978.

2 One gigawatt hour (Gwh) = 1 x 10^6 megawatt hours.

Slave Delta.

Economically, the Slave River Delta is an important source of muskrats for trappers of Fort Resolution, located at the southern edge of the delta on the shore of Great Slave Lake. At peak years, during their cyclic high, as many as 46,000 muskrats have been caught in the delta (Law, 1950). Moose (*Alces alces*), lynx (*Lynx lynx*), beaver (*Castor canadensis*), snowshoe hare (*Lepus americanus*) and black bear (*Ursus americanus*) are also found in good numbers on the delta and are harvested by trappers and hunters from Fort Resolution. Historically the white spruce (*Picea glauca*) stands along Nagle Channel have provided lumber for sawmills built on the delta and in Fort Resolution by the Catholic Church and Federal Government. Spruce lumber from the Slave Delta was used in the construction of Inuvik, N.W.T. (Beaulieu, Pers. Comm., 1977).

Environmental disruption of the delta would have economic repercussions within the village of Fort Resolution as most families depend on the delta for meat hunting and fur trapping as an extra source of country food and income (Law, 1950; Smith, 1975; Bodden, 1979[1]).

The Slave Delta is classified as a critical wetlands area by the Mackenzie Basin Intergovernmental Liaison Committee (1977) which stated that "the Slave River Delta has become prominent as a potentially sensitive and ecologically important area ... the resources

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[1]K. Bodden, M.A. Candidate in the Department of Geography, The University of Alberta, is in the process of completing a thesis on the use of the Slave Delta resource base by the residents of Fort Resolution. He is scheduled to defend the thesis in the spring of 1979.

(of the delta) upon which residents (of Fort Resolution) rely are themselves reliant on the natural regime of the delta." In order to evaluate the downstream environmental repercussions of an impoundment upon the delta, comprehensive baseline research was needed. The importance of this type of research was underlined by Berger (1977:58) during his inquiry into the Arctic Gas pipeline proposal along the Mackenzie Valley:

> "Before assessing change, it is absolutely essential to understand first what is an undisturbed or normal condition. Only then can we adequately appreciate many of the effects of impact. A great deal of work over a period of years and at all seasons of those years is required to demonstrate the range of normal, annual and seasonal variations and to define the major factors that make the ecosystem function. Complementary to this work there should be studies of specific anticipated impacts."

As further stated by Dunbar (1971:5),

> "We have been caught in a state of scientific near nudity in the particular respect in which we now so urgently need protective covering; namely, knowledge of what proposed developments will do to the environment in precise terms, and knowledge of what should be done to conserve and protect."

1.6 Literature review

Many studies on the vegetation of the Great Slave Lake-Athabasca region were done during the first half of this century. These include Camsell (1916), L.C. Raup (1928), H.M. Raup (1928, 1930a, 1930b, 1946) and Harper (1931). Harper sampled the vegetation of the Slave Delta but made little mention of it, except for reporting a great abundance of balsam poplar (*Populus balsamifera*), some red raspberry (*Rubus melanolasius*), red osier dogwood (*Cornus stolonifera*), cattail (*Typha*

latifolia), and bog star (*Parnassia palustris*). Some notes on the phenology of these species were also made. Raup (1946) classified the Slave Delta area within the 'white spruce flood plain' of the lower Slave River. His brief account of the delta consisted largely of a description of the white spruce and balsam poplar stands: "the higher parts of the ... Slave Delta are covered with forests of white spruce and balsam poplar ... these rich woods were limited to natural levees" (Raup, 1946:19). He also briefly described the extensive grass and sedge meadows on the distal portions of the delta.

A complete history of exploration and early scientific research in the Great Slave Lake region is given in Hume (1921) and Raup (1947).

1.6.1 Recent studies

Recent biophysical studies on this portion of the Great Slave Lake area include work by Brown (1950), Law (1950), Day (1972), Raup (1975), Gill (1976) and Gill *et al.* (1977).

The most recent geological description of the Fort Resolution area was written by Brown (1950). This includes a description of the succession of Precambrian rocks of the Laurentian Shield to the east of the study area. The limestone outcrops of Mid Devonian age near Fort Resolution are discussed and their areal extent shown on an accompanying map. The potential economic geology of the region is evaluated qualitatively.

Law's (1950) study of muskrat ecology on the Slave River Delta was the first relatively comprehensive ecological work on this area. Although the focus of the study was on the muskrats' life

history, behaviour, population dynamics, and physiology, the vegetation is qualitatively described for some parts of the delta.

Law also describes four ways by which the depth of water is controlled on the delta. The first is the seiche effect from Great Slave Lake which was later reported by Kemper (1972). The second is the seasonal lowering of the water table on deltaic islands. Rapid siltation of channels and formation of new distributaries during periods of high water and correspondingly high sediment loads also causes changes in water depths. Sudden thaw and heavy rains in the upstream portion of the basin are the fourth factor attributed by Law to govern water levels in the delta.

Day (1972) examines soil deposits in the Slave River Lowlands, including parts of the Slave Delta. A generalized soil map of the delta was produced from this study. He defines most of the delta soil under the broad term 'alluvial deposits' or Cumulic Regosols "which usually have only a very thin organic horizon (L) which is underlain by calcareous stratified alluvium (CK) that ranges in texture from loamy sand to silty clay loam" (Day, 1972:30). These soils reflect the irregular pattern of flooding and sedimentation with intermittent periods of organic buildup on the soil surface during low flood periods. The soils in the white spruce assemblages are chiefly Cryic Regosols, since permafrost occurs within 30 cm of the surface. There are patches of Rego Humic Gleysols in the white spruce stands exhibiting a well-developed organic horizon. Day also briefly describes the vegetation-soil association observed on the delta.

Raup (1975) discusses in general terms certain aspects of plant dominance in wetlands of the Great Slave Lake-Lake Athabasca region. This paper was based on fieldwork dating back to 1940 and on related studies in the area. In classifying shoreline vegetation in the area, Raup concluded that the concept of plant assemblages was more practical than that of plant communities. Plant communities have a similar floristic composition among sample plots which does not occur in these northern wetlands. Instead, there is a wide variation in species composition among sample plots which necessitates a term such as assemblage because it "carries few implications of relationships that are non-existent or unknown." This variation between sample plots or assemblages was attributed to biotypic or ecotypic variations within populations which in turn have been conditioned historically to the frequent flooding that occurs in these wetland areas (Raup, 1975:138).

A more recent survey (Gill, 1976) which focuses directly on the Slave Delta revealed areas of classical plant succession very similar to those found on the Peace-Athabasca and Mackenzie Deltas. This study also revealed large areas of contagiously distributed (as defined by Whittaker, 1975) aquatic and semi-aquatic plants in the distal portions of the delta. A contagious pattern in the distribution of plants is one with little causal relationship to environmental gradients. Similar situations are discussed by Raup (1975) for this region. He does not deal with the causes of this type of distribution but focuses on the problems encountered in classifying such vegetation. Raup also discusses the wide ecological amplitudes of some dominant

shoreline plants and the lower tolerance ranges of the sub-dominant species.

1.6.2 Related studies

Although the environmental and ecological literature on the Slave Delta is limited, a number of related studies deal with one or more of the biophysical elements common to northern deltas and deltas in general.

1.6.2.1 The delta environment

As stated by Doherty and LaRoi (1971:202),

> "Compared to other landscape systems the active river delta with its many changing biological and physical properties, is a particularly complex and dynamic entity. The vivid intricate and shifting pattern of aquatic, semi-aquatic and terrestrial ecosystems that characterize the surface of an enlarging delta is the net result of geomorphological, fluvial and biological processes operating within the delta. However these processes are manifestly controlled by conditions and events occurring over the whole of the river watershed. The annual influx of water and sediment that covers varying fractions of the delta is responsible for the maintenance of a youthful age structure, ie: a preponderance of hydrarch, successional ecosystems on the delta. The flood is also the chief architect of new channels, islands, back-water basins, as well as the main source of energy and materials for the upgrading of levees, irrigation and fertilization of ecosystems and containment of otherwise advancing woody and also climax vegetation."

1.6.2.2 Initial construction-the delta as a geomorphological unit

Deltaic formation is governed by the deposition of sediment, both in the form of bed load and suspended sediment as a river enters a relatively stable body of water, whether it be a lake or an ocean. The mode of deposition of the river sediment is governed

by the relative densities of the two bodies of water, in this study the Slave River and Great Slave Lake.

Bates (1953) describes three types of inflow, hypopycnal, homopycnal and hyperpycnal - each relating to different density combinations of the river water and lake water. Homopycnal inflow occurs where the densities of both the river and the lake are equal. Homopycnal inflow results in deposition of sediment forming the classic topset, foreset and bottomset beds of the submarine delta (Gilbert, 1885; Bates, 1953). As resistance to the inflow is minimal if the densities are equal, the sediment is dispersed at the mouth along the three dimensional axial jet (Thakur and MacKay, 1973) and deposition is more or less spread evenly in areal extent at the mouth of the delta distributary barring interference from the lake in the form of current or wave action. However the erosional forces of the lake disrupt the ideal axial plane condition and sediment entering the lake is deposited irregularly. This is observed in Great Slave Lake along the outer islands of the Slave Delta. Axelsson (1967) points out that the geometry of the river mouths, the depth conditions, the frontal shape of the delta, the grain size of the transported material, wave action and water level variations play a large role in the physical behaviour of the axial or plane jets at the concourse of the discharging channels.

Galloway (1975) formulated a model of factors determining the morphology and stratigraphy of a delta system. This system (Figure 1.1) recognizes the importance of factors modifying delta

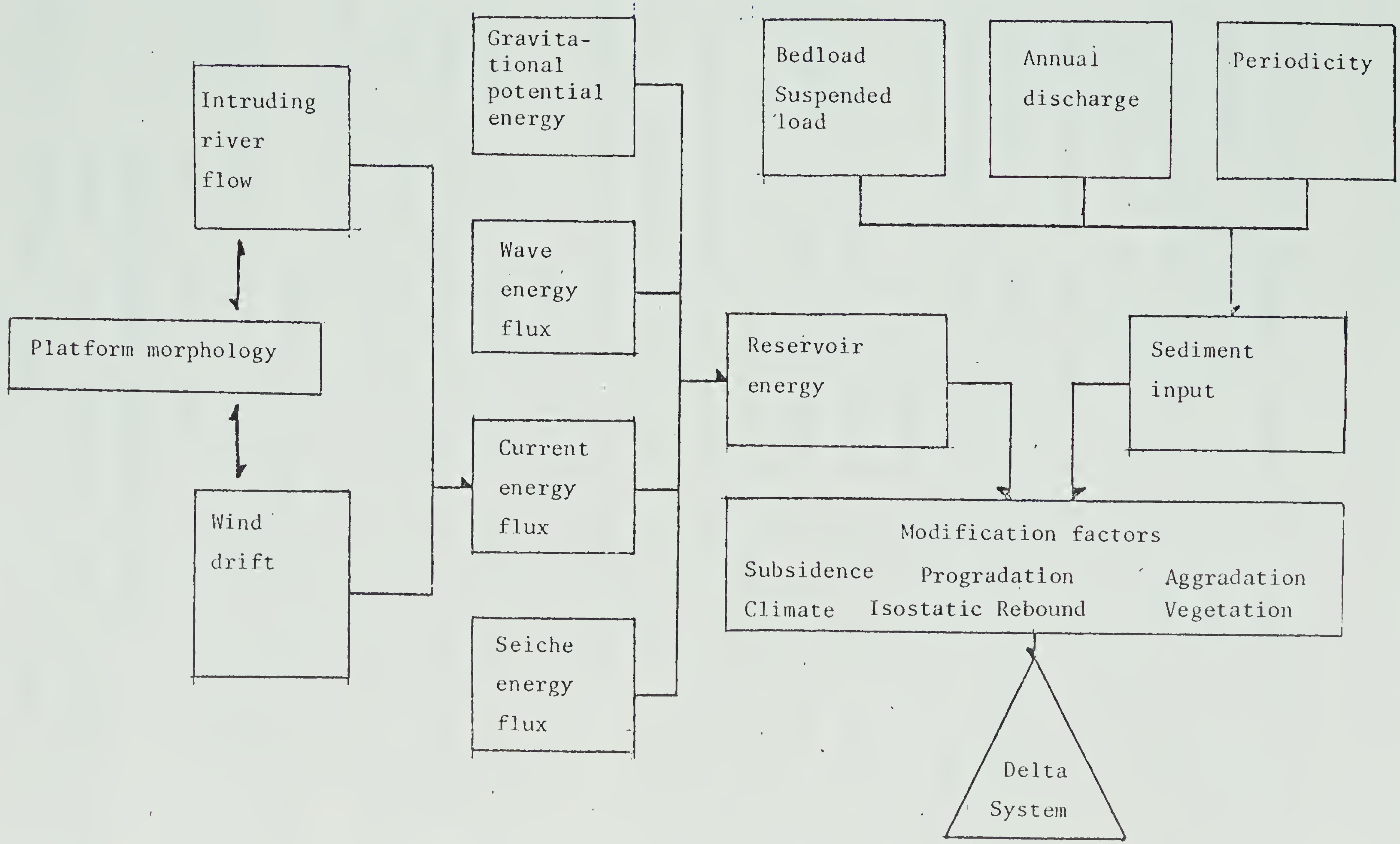


Figure 1.1: A model of deltaic systems (modified from Galloway, 1973).

formation such as subsidence, aggradation, climate and vegetation. The processes outlined in Galloway's model are recognized by several authors and their significance in relation to each other is discussed (Kuiper, 1960; Silvester and de la Cruz, 1970; Fraser (in Oglesby *et al.*), 1972; Thakur and MacKay, 1973; Coleman and Wright, 1975). It is felt by these authors that the multiplicity of factorial combinations influencing delta growth are too complex to be generalized in a simple model.

As the submarine delta is formed the gradient of the river (determined by the bedload - Kuiper, 1960) extending from the apex of the newly forming delta to the distal portions bordering the lake decreases causing deposition of larger grain size material near the apex and smaller grain size particles near the foot of the delta. Dahlskog *et al.* (1972) found similar results of grain size distribution in the Kikkjokk delta in northern Sweden.

Axelsson (1967) and Einstein (1972) describe the process of channel closure in deltas. Kuiper (1960) discusses the formation of new channels that usually occur in poorly developed levees near the distal portions of deltas where vegetation growth is not dense enough to prevent erosion and avulsion of the levee.

Channel development (and closure) is discussed in detail by Arnborg (1948), Pitty (1971), Blench (in Oglesby *et al.*, 1972), and Thakur and MacKay (1973).

1.6.3 Geomorphological landform and process

Dirschl (1971:11) describes a delta as a "dynamic system that grows downstream as it matures at the upstream end. In this

process of maturing, delta sites develop toward drier and more stable soil moisture conditions."

Barrell and Clark (1912) and Dahlskog *et al.* (1972) followed W.M. Davis' (1899) example and discussed delta formation using his terms for the geographical cycle of youth, maturity and old age. The youthful stage is applied to the developing outer delta; the mature stage occupies the mid portion of the delta where the landforms and corresponding vegetation have not yet reached a climax stage; the portion of the delta near the apex is equated with old age.

1.6.3.1 Outer delta

Dahlskog *et al.* (1972) describe in detail the youthful stage of the Kvikkjokk Delta in Sweden. This delta exhibits a classic development of cleavage bars much like those forming on the outer delta of the Slave River. The geomorphological evolution of cleavage bars is initiated by the formation of submarine levees extending from the mouths of the discharging channels. Stabilization of the levee is aided by the invasion of pioneer species of vegetation. The interiors of these formations remain below the level of the surrounding levees. The open side of the cleavage bar may be subject to wave shoal development (Gill, 1971) as a result of lake wave action. These inter-levee depressions provide rich habitat for emergent vegetation as the fine grain sediment that is deposited here enhances the ability of the substrate to accumulate nutrients by ion adsorption to soil particles. As the topset beds expand outward into the lake, a platform is provided for further cleavage bar development. The direction of topset

bed development and corresponding cleavage bars is determined by the orientation of distributaries carrying the bedload (Kuiper, 1960). This portion of the delta is the most susceptible to channel bifurcation as the levees are poorly developed and inhabited only by pioneer plant species. The levees in the older parts of the delta are higher above river level and are colonized by vegetation possessing sufficient rooting systems to help stabilize the levees against avulsion.

1.6.3.2 Levee and point bar development

Gill (1971a) and Dahlskog *et al.* (1972) describe the erosional and depositional processes that contribute to cut bank levee and point bar development. Natural levee formation is discussed by Wolman and Leopold (1957) and Gill (1972b).

Point bar development is widely discussed in the literature (Leopold and Wolman, 1960; Leopold, 1962; Nunnally, 1967; Morisawa, 1968; Wolman and Leopold, 1957; Gill, 1972a). Helicoidal flow (formerly called the cross channel velocity component by Leopold, 1962), the hydrological phenomenon responsible for sediment deposition on point bars is discussed by Gill (1972a). Morisawa (1968) attributes the buildup of point bars to lateral accretion of sediment through helical flow. Leopold and Wolman (1960) describe the deposition of different particle sizes on the cone of the point bar; they conclude that coarser material generally accumulates near the point bar crest. They also attribute lateral downstream channel migration to the "bank erosion of the concave bank and concurrent deposition on a point bar across the channel" (Leopold and Wolman, 1960:785). In an earlier paper Wolman

and Leopold (1957) discuss point bar formation in terms of the laterally shifting wave theory.

1.6.3.3 Relationships between landform and vegetation in deltas

According to Vann (1959), a vegetational approach to the study of deltaic development has been rarely utilized by geomorphologists. Axelsson (1967) adds that little is known of the significance of vegetation in the development of a delta's morphological pattern. However, later work by Gill (1971, 1972a, 1972b, 1975a) emphasizes the importance of the interrelationships between annual flooding, sedimentation processes, and the distribution of seral communities in the Mackenzie River Delta.

Bliss and Cantlon (1957) define the allogenic and autogenic processes operating on a delta underlain by permafrost in northern Alaska, and present a graphic model of the relative importance of various vegetation types in successional sequence as related to the decreasing influence of the river, the decreasing depth of sand and silt, and the decreasing depth of the active layer. Gill (1971, 1972a, 1972b) explores the allogenic and autogenic factors responsible for plant succession on the Mackenzie Delta. This interaction of flooding, sedimentation, and plant succession operates on the Slave Delta as well.

The ecological relationships between water levels and successional vegetation on deltas are dealt with in detail by Reinelt *et al.* (1971) and the Peace-Athabasca Delta Project Group (1971, 1972).

Dirschl (1970, 1972) describes the vegetation

patterns of the Saskatchewan River Delta in relation to age of landform and flooding history. Stevens (1971) describes the possible ecological effects of diverting water from the Mackenzie River Basin to the Saskatchewan-Nelson Basin and discusses the present relationships between seasonal water levels and successional wetland vegetation. Concerning the Slave Delta, he states that "the process of delta building is proceeding very rapidly, and natural plant succession is able to clothe the land with forest only as conditions for spruce regeneration become suitable" (Stevens, 1971:16).

1.6.3.4 Downstream implications of hydroelectric dam construction

Environmental impact assessment prior to dam construction is relatively scarce in circumpolar countries, including Canada, where most impact studies commence during or after construction of an impoundment (Reinelt *et al.*, 1971; Peace-Athabasca Delta Project Group, 1971, 1972; Fraser, 1972; Glooschenko, 1972; Richardson, 1972; Taylor *et al.*, Gill and Cooke, 1974).

Geomorphological and hydrological implications of impoundment construction on northern rivers are discussed by Kuiper (1960), Day (1971), Taylor *et al.* (1972), Armstrong (1973), Gill (1973), Kellerhals and Gill (1973), Kerr (1973) and Maddock (1976).

Doherty and LaRoi (1971) state that, before closure of the Bennett dam influx of water and sediment during the spring flood was responsible for maintaining the Peace-Athabasca Delta in a youthful stage.

Generally speaking, disruption of a river system

which causes changes in its normal discharge and in the concentration of suspended sediment and bedload, will alter the biophysical regime of downstream wetlands because their vegetation seres are a direct response to the frequent inundation by flood waters and the deposition of sediment. Gill (1973) emphasizes the importance of the spring flood in maintaining this pattern of growth in northern deltas. Day (1971) discusses the effects of river regime change through dam construction on downstream floodplains. He states, "alterations in the energy distribution of river systems caused by dams should be expected to produce an imbalance in existing vegetation patterns with river channels and on flood plains" (Day, 1971:4).

Once factors governing allogenic succession are largely eliminated, Gill (1978) postulates a rapid increase in the aging process of a delta. Elimination of flooding and sedimentation in a delta enables colonization of the ground surface by bryophytes which leads to the invasion of permafrost as soil temperatures decline.

Once the delta system has been stabilized, a relatively new ecosystem develops (Day, 1971). The nutrient budgets in the soil change as the pH is lowered, resulting in the elimination of beneficial nitrogen producing bacteria. This is one of many factors leading to the decreased productivity of a stabilized delta.

CHAPTER TWO

STUDY AREA

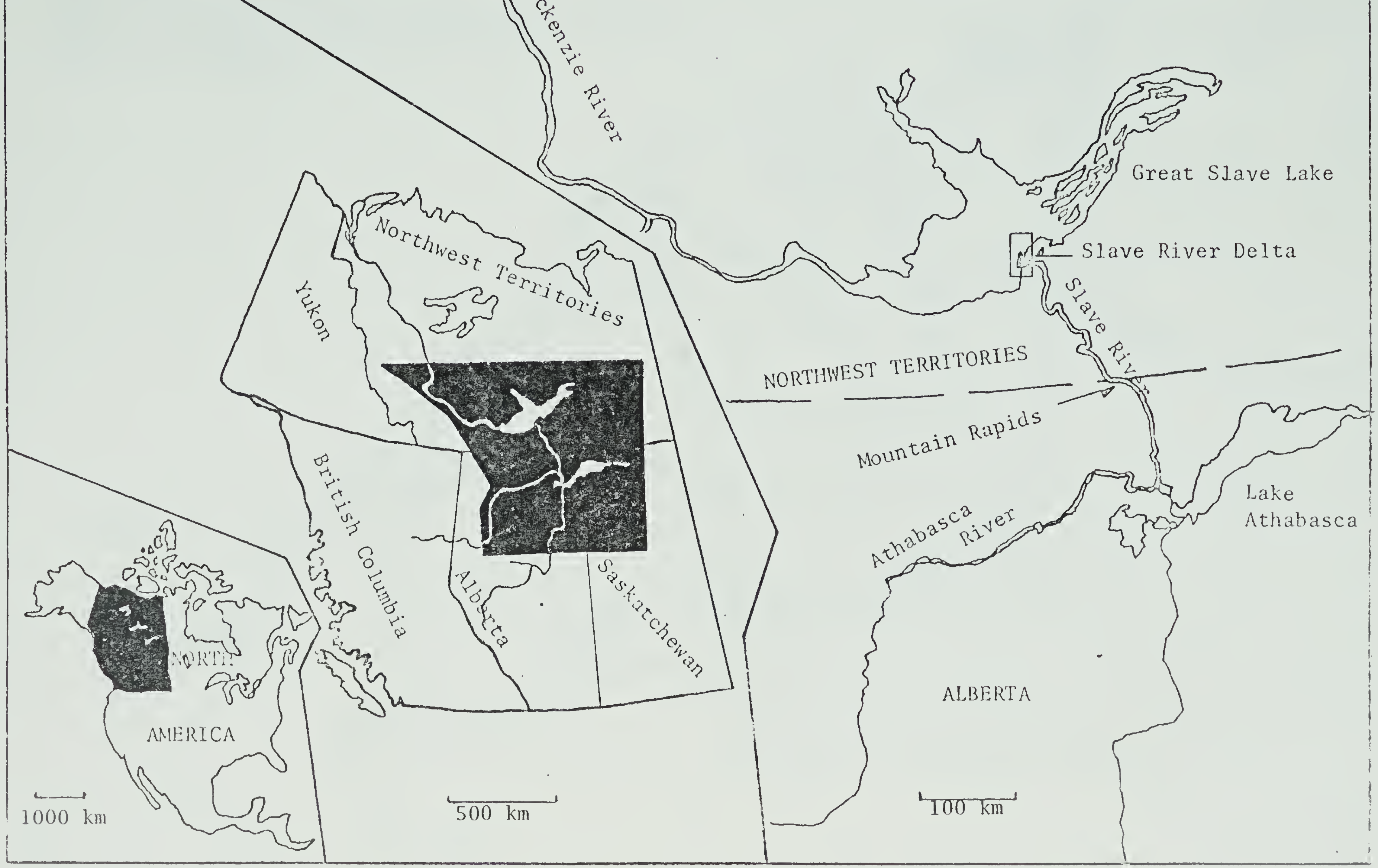
2.1 Introduction

The active delta of the Slave River is located on the south shore of Great Slave Lake, Northwest Territories, at $61^{o}15'$ N, $113^{o}30'$ W (Figure 2.1). This arcuate shaped delta (as defined by Silvestor and de la Cruz, 1970) is approximately 210 km^2, 78 km^2 of which is made up of active distributaries. The main channels and islands of the delta are shown on figure 2.2 and their lengths and areal extents are shown in Table 2.1.

For this study, Nagle Channel is used to delimit the southern border of the active delta. This channel has been relatively stable (i.e., little shifting) since at least 1922 (compare Figure 4.13 and 4.16). The northeastern border is defined as a line extending from the apex of the delta (a point in the centre of the Slave River at the centre of the Slave River at the origin of Nagle Channel at $61^{o}15'$ N, $113^{o}30'$ W), northeastward to an island in Jackfish Bay at $61^{o}21'$ N, $113^{o}33'$ W. The northeastern boundary is arbitrarily used to define the field area, although the active delta does extend beyond this line in places. The shoreline of Great Slave Lake serves as the northwest boundary of the study area.

The semi-aquatic nature of the delta is shown in Figure 2.3. Fifty-one percent of the delta is submergent, either at or below water

Figure 2.1 : Study area



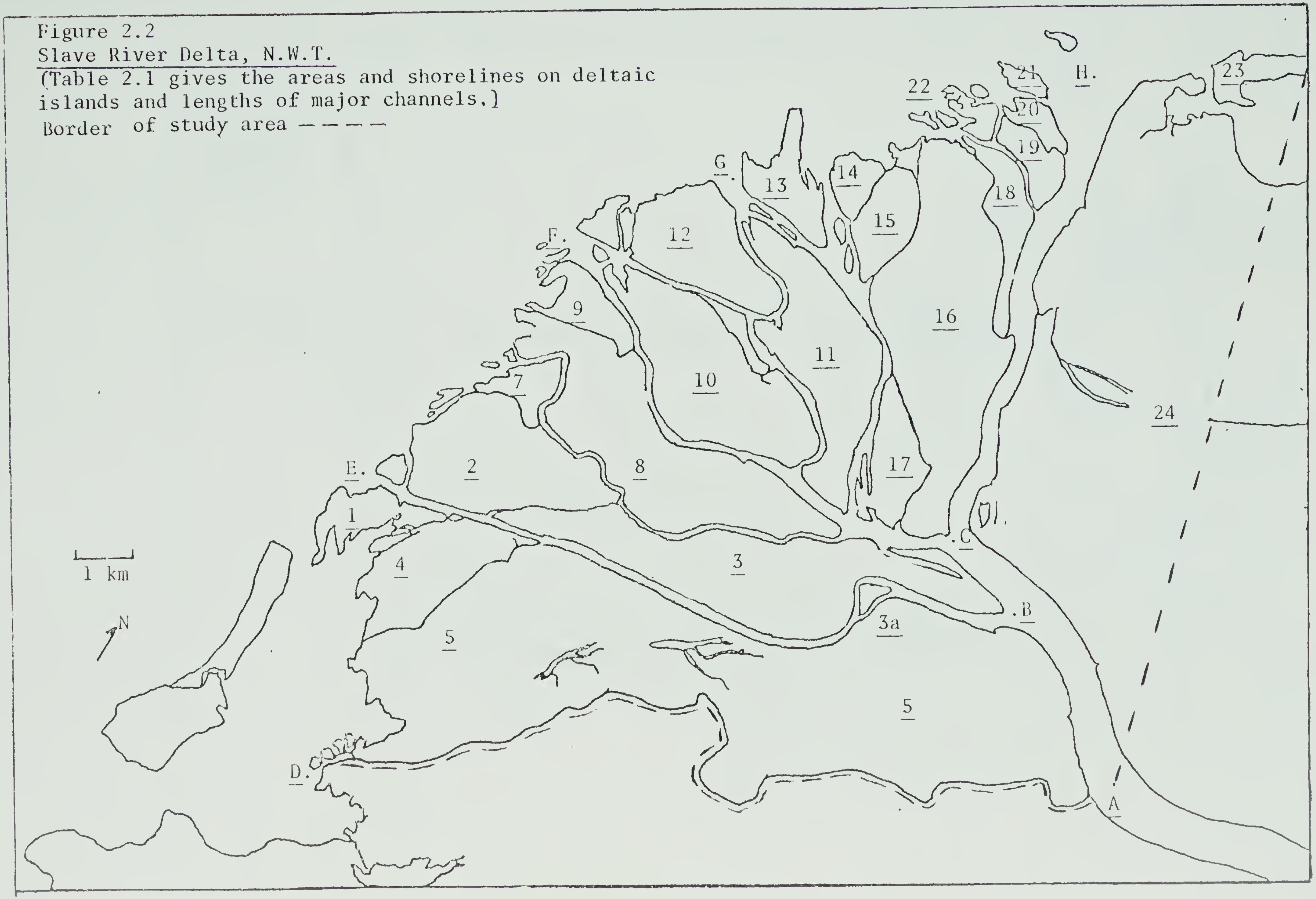


Figure 2.2
Slave River Delta, N.W.T.
(Table 2.1 gives the areas and shorelines on deltaic islands and lengths of major channels.)
Border of study area – – – –

Table 2.1: Areas and shorelines of deltaic islands.
Lengths of major channels (refer to Figure 2.2).

Island	Area (km^2)	Shoreline (km)
1	.99	9.38
2	4.14	9.24
3	6.66	21.43
3a	.15	1.69
4	2.57	22.37
5	24.92	90.69
7	.77	2.20
8	6.36	17.00
9	1.07	7.52
10	5.14	16.41
11	4.14	17.24
12	3.19	14.64
13	1.28	1.88
14	.62	4.24
15	1.26	5.99
16	7.07	19.73
17	1.46	9.90
18	2.00	8.47
19	.73	4.09
20	.41	5.41
21	.27	3.40
22	.46	6.42
23	.64	4.84
24	37.30	68.00
Total	113.60 km^2	372.18 km

River channel	Length (km)
A-H (Resdelta)	10.00
C-G (no name)	4.89
C-F (no name)	6.85
B-E (Steamboat)	9.24
A-D (Nagle)	12.78

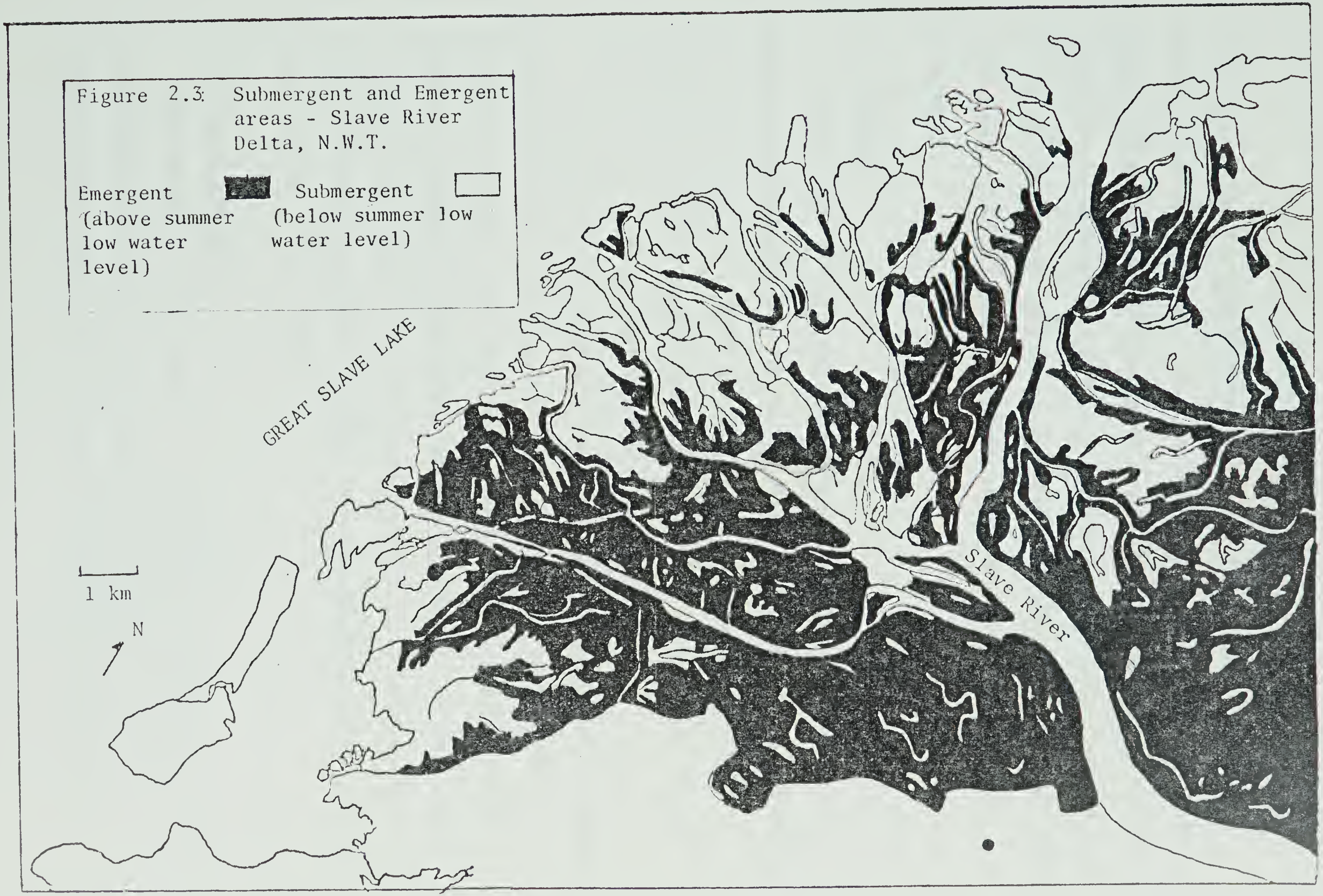


Figure 2.3: Submergent and Emergent areas - Slave River Delta, N.W.T.

level during the low summer water levels of Great Slave Lake. The remaining 49% is emergent, above the summer low water level. Islands along the outer delta, the youngest landforms, are almost entirely submergent. The older islands in the centre of the delta are approximately 25% submergent, while the areas of the delta closest to the apex, specifically the elevated area north of Nagle Channel, are only 6% submergent.

2.2 Geology

The geology of the area encompassing the Slave River Delta is mapped and shown in cross section in Figure 2.4. The map illustrates the areal extent of the deltaic deposits. The borders of the Slave Valley on the cross section are defined by the Taltson River on the eastern side and Little Buffalo River on the west.

Geologically, the area between Great Slave Lake and Lake Athabasca can be divided into two provinces, the Laurentian Plateau and the Mackenzie Lowlands. The Slave River Valley forms a boundary between these two provinces, the Precambrian crystalline rock of the Laurentian Plateau to the east of the valley and the Palaeozoic sedimentary rock of the Mackenzie Lowlands to the west. A comprehensive geology of the area is given by Raup (1946).

2.3 Glacial origins

Approximately 15000 years BP, the Keewatin Ice Sheet extended into the southwestern corner of the present day Northwest Territories. Cameron (1922) reports that ice lobes extended up the Peace River

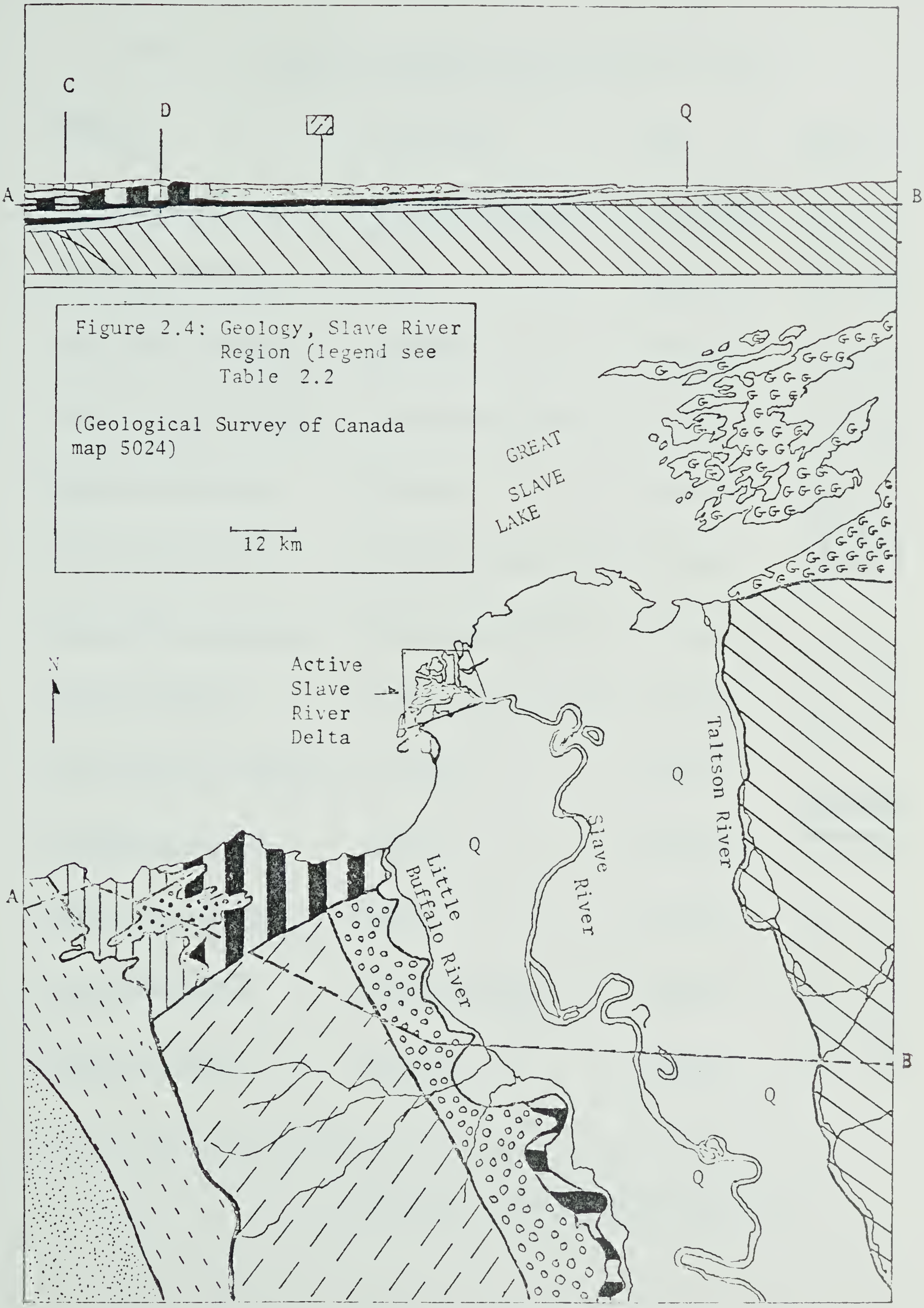


Figure 2.4: Geology, Slave River Region (legend see Table 2.2

(Geological Survey of Canada map 5024)

Table 2.2: Key to the geology of the Slave River Delta region (as shown in Figure 2.4)

Reference	Composition	Age	Key
Delta formation	Alluvial deposits	Quaternary	Q
Hay River formation	Shale	Devonian	
Slave Point formation	Limestone	Devonian	
Sulphur Point formation	Limestone and shale	Devonian	
Presqu'ile formation	Dolomite	Devonian	
Pine Point formation	Limestone and dolomite	Devonian	
Mirage Point formation	Gypsum and dolomite	Devonian	D
Nyrling formation	Gypsum and limestone	Devonian	
Little Buffalo formation	Limestone	Devonian	
Chinchaga formation	Gypsum	Devonian	
Buffalo River member	Shale	Devonian	C
Laurentian Shield	Granitic gneiss	Archean	
Laurentian Shield	Granite	Archean	

Cross section sample in Figure 2.4, denoted by: A----B

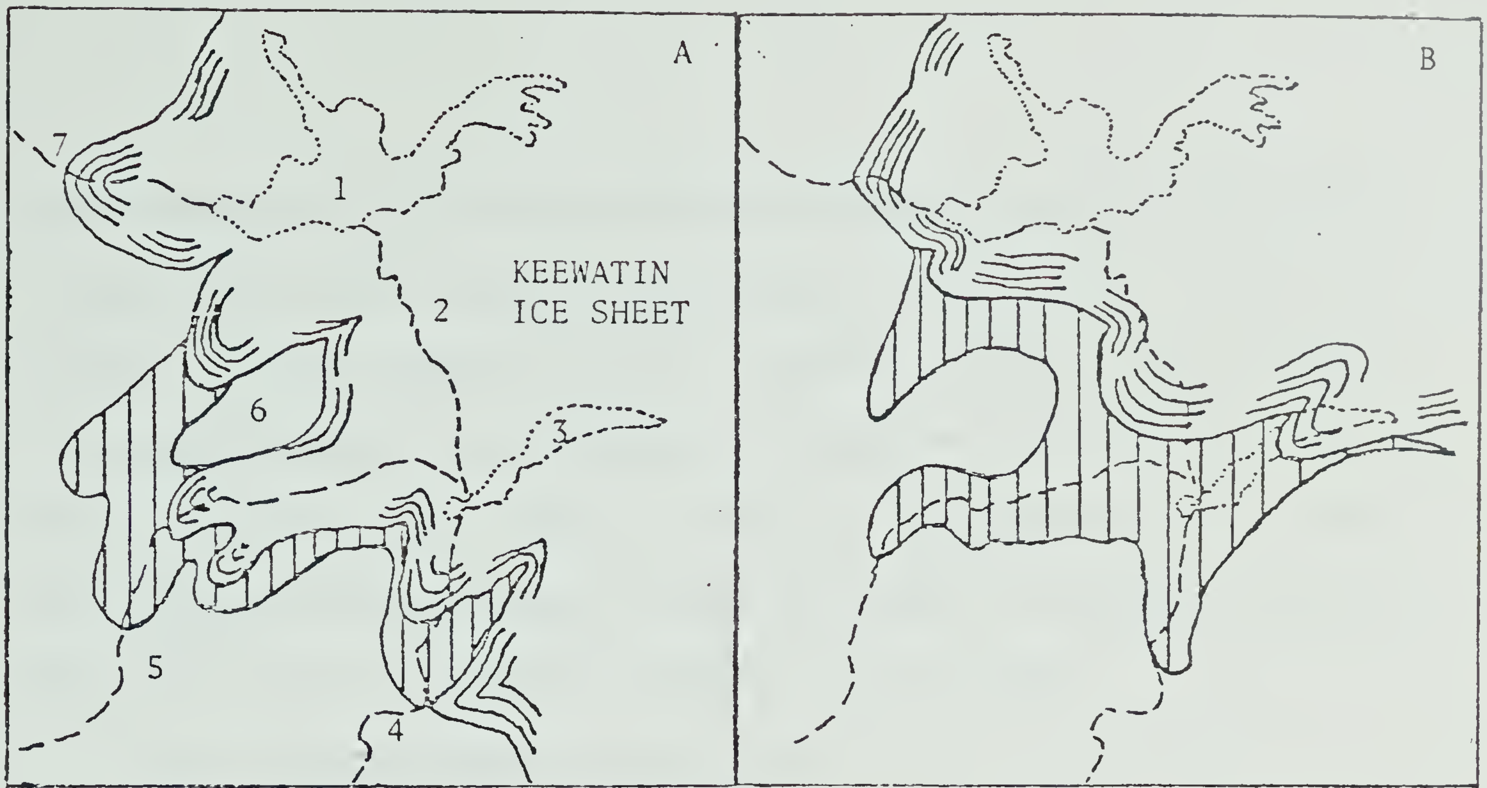
(Geological Survey of Canada map 5024)

Valley. One lobe extended up the Athabasca Valley, the main body of the lobe resting in the Lake Athabasca basin. Another ice tongue extended westward into the Selwyn Mountains preventing drainage from post-glacial Lake McConnell down the Mackenzie Valley.

Glacial retreat began in this region approximately 10000 years BP (Bryson *et al.*, 1969), followed by the formation of large Glacial Lake McConnell as shown in sequence in Figure 2.5. Drainage followed the present Churchill River system into Hudson Bay (Cameron, 1922; Douglas, 1959).

It was originally postulated by Cameron (1922) that isostatic rebound in the Churchill River area coupled with retreat of the Selwyn Mountain ice tongue resulted in the drainage of Glacial Lake McConnell northward down the Mackenzie River. As the land continued to rise and the ice sheet diminished, lowering of water levels in the post glacial lake resulted in the differentiation of the large body of water into two separate lakes. These two water bodies occupied the basins of present day Great Slave Lake and Lake Athabasca although water levels were considerably higher (approximately 200 m a.s.l.) than they are today (approximately 155 m a.s.l.). Post glacial Lake Athabasca and Great Slave Lake were joined by the Slave River.

After the post glacial lakes dropped to the 200 m a.s.l. elevation, alluvial material carried by the Peace and Athabasca rivers entered the southern arm of Great Slave Lake and formed a delta. As lake levels dropped, the delta expanded northward eventually filling in the southern arm. Deltaic and lacustrine deposits are interspersed, evidence of the



Outline map showing the probable position of Keewatin Ice Sheet and Glacial Lake McConnell expansions when the water stood at the A) 485 m, B) 335 m, C) 245 m, and D) 210 m above sea level.

1. Great Slave Lake
2. Slave River
3. Lake Athabasca
4. Athabasca River
5. Peace River
6. Caribou Mountains (ice free)
7. Mackenzie River

Figure 2.5 : Recession of Keewatin Ice Sheet, formation of Glacial Lake McConnell and subsequent formation of Great Slave Lake and Lake Athabasca water bodies (approximately 8500 BP).
(Cameron, 1922)

delta expansion as lake levels dropped. Cameron (1916:9) stated that "these deposits are typical cross bedded sands and silts of fluvial origin." Later, Cameron (1921:17) referred to these fluvial deposits as being "intimately associated with lacustrine deposits of a somewhat earlier period." Over the past 8000 years this southern arm of Great Slave Lake has slowly filled in with alluvium to its present position where the active delta still progrades into the lake.

2.3.1 Local evidence of glaciation

Moose Deer and Round islands, located within 2 km of the Slave Delta, are roche moutonnees (Cameron, 1922) and provide good evidence of local glaciation. Glacial striations occur in the limestone outcroppings near Fort Resolution (GSC map 5022).

As the water level of post glacial Great Slave Lake receded and isostatic rebound occurred, beaches were formed during periods of stability. These beaches are evident today southwest of the delta. A series of four beaches extends south of Nagle Channel in a line running from the apex of the delta to Fort Resolution. Hume (1921:19) reported that "such beaches are also seen near Resolution on the south side of the lake ... the beaches shown here as interrupted ridges of limestone shingles on which there is seldom any vegetation." This still holds, as these beaches provide habitat for only a sparse population of juniper (*Juniperus horizontalis*) and lichens.

2.4 Hydrology

The Slave River is approximately 500 km in length, extending from the confluence of the Peace River and Riviere des Rochers to Great

Slave Lake. This river provides a common drainage for the large catchments of the Peace (303000 km^2), Athabasca (162000 km^2) and Fond du Lac (69000 km^2) rivers. The Peace, Athabasca, and Fond du Lac drainage basins comprise 86% of the 620000 km^2 Slave River catchment. The portion of the catchment located between Lake Athabasca and Great Slave Lake which drains directly into the Slave River makes up 4% or 24,000 km^2 of the entire drainage basin. The remaining 10% constitutes land draining into Lake Athabasca.

Although 75% of the drainage basin of the Slave is comprised of low natural storage rivers (the Peace and the Athabasca) which have a high fluctuation in annual discharge, the Slave's discharge is somewhat modified by the presence of Lake Athabasca. The Slave River's annual hydrograph has a profile associated with moderately high storage catchments. The mean date of ice breakup on the delta is 11 May, but the range is large (up to several weeks), as breakup is a function of weather conditions over the entire basin during late winter and early spring. A seasonal peak in discharge usually occurs in early June, but this is not always the case. Peak discharge has occurred as late as 19 July (1971) and as early as 5 May (1974). The hydrographs over the past 17 years indicate a bimodal peak in discharge as demonstrated for 1977 in Figure 2.6. The early peak is the result of spring snowmelt and breakup on the Interior Plains draining into the lower catchment. The second peak in early June is the result of more distant snowmelt in the western cordillera.

The mean annual discharge over the past 17 years is 3550 m^3/s,

Figure 2.6 : Slave River Discharge (Q) 1977

* December data missing (Water Survey of Canada, 1977)

ranging from a low of 2540 m^3/s in 1970 to a high of 4560 m^3/s in 1973 (Water Survey of Canada, 1977).

The hydrologic forces exerted by the Slave River prograde the delta into Great Slave Lake while those exerted by Great Slave Lake operate in the reverse to restrain delta growth. The lake's erosional forces on the delta are due in large part to the prevailing wind direction which is northwest during the ice free months. Wave action on the outer delta almost continually erodes the shoreline while the river (except during the months of ice cover) deposits sediment replacing that lost to the lake.

A lake level rise along the outer delta of almost .24 m in a few hours has been recorded by Law (1950). This was due to a seiche created by high winds on Great Slave Lake[1]. The prevailing wind direction promotes a lateral growth of the delta as opposed to an outward growth. The discharge of the river creates a current in Great Slave Lake which aids in the arcuate formation of the delta. An explanation of this is given in section 4.3.1.

2.5 Sediment deposition

The alluvium making up the Slave Delta originated largely from the western cordillera and the glacial overburden of the Interior Plains through which both the Peace and Athabasca rivers flow. The deposition of sediment at the mouth of the Slave River is a hydraulic response to the large discharge of water entering the relatively

[1]An explanation of the lake-seiche phenomenon is given by Hutchinson (1957).

TABLE 2.3

Fort Resolution Climatic Data (1941-1975)

Mean Monthly Temperatures (^{o}C)

J	F	M	A	M	J	J
-26.1	-23.0	-16.7	-5.6	5.0	11.7	15.6

A	S	O	N	D	Mean Annual Temperature (^{o}C)
14.4	7.8	.56	-10.6	-21.3	-3.92

Mean Monthly Precipitation (cm)

J	F	M	A	M	J	J
1.42	1.37	1.19	1.19	1.55	2.44	3. 6

A	S	O	N	D	Annual
3.30	3.81	3.38	4.37	1.98	29.57

(Environment Canada, 1975)

tranquil Great Slave Lake.

2.6 Climate

From the weather records available (discontinuously from 1931 to 1975), the study area can be classified as a Continental Subarctic climate, Dfc according to the Koppen-Geiger classification (Strahler, 1976).

Temperature and precipitation data for Fort Resolution are shown in Table 2.3 (Environment Canada, 1975). Complete data are available from 1931 to 1975; after 1975 the Department of Transport closed the Fort Resolution weather station. Records indicate a mean annual temperature (1941-1975) of -3.92^{o}C with a summer mean maximum of 15.6^{o}C in July and a winter mean minimum temperature of -26.1^{o}C in January. Only three months, June, July and August, have mean temperatures greater than 10^{o}C.

Precipitation is well distributed throughout the year. The maximum occurs in November with a 29 year mean (1941-1975) of 4.37 cm, 4.20 cm of which fell as snow. March and April share the seasonal lows for precipitation: 1.20 cm with .99 cm recorded as snow. Between 1941 and 1975 Fort Resolution received an annual average of 29.57 cm of precipitation, 14.17 cm as rainfall and 15.39 cm as snowfall.

The growing season for Fort Resolution is approximately from 15 May to 23 September, a duration of 130 days. The relatively long growing season for this latitude is due to the re-radiation of stored energy into the atmosphere from Great Slave Lake during September. This release of heat into the cooling air mass is directed southeast

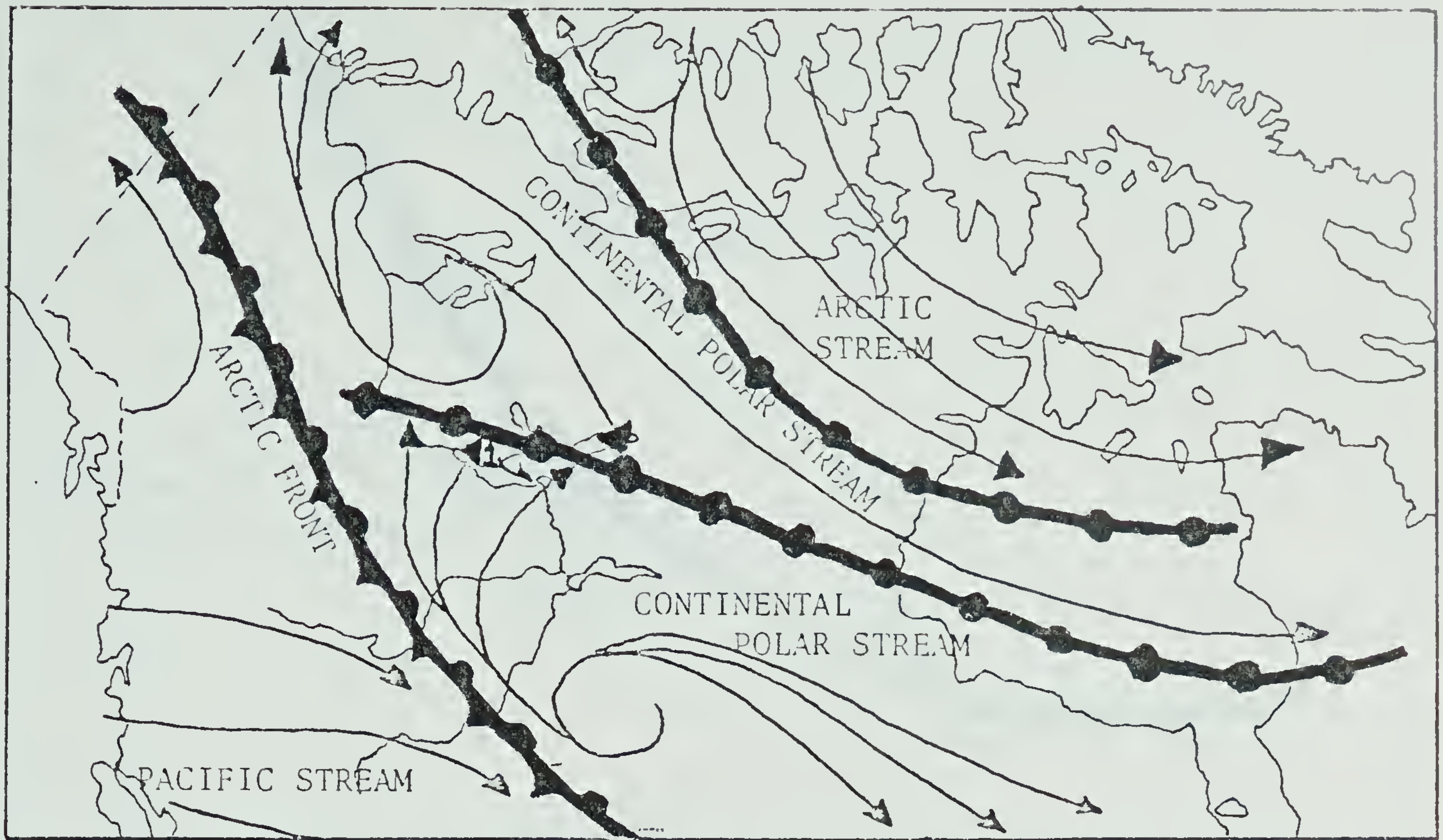
by prevailing Pacific wind systems as the average position of the Arctic front has not yet descended south of Great Slave Lake.

This region along the south shore of the lake is affected by air masses from different source areas depending upon the seasonal position of the Arctic front (Figures 2.7, 2.8). During the summer and early fall, this region is under the influence of cool, moist Pacific air, a product of the Maritime Polar air mass. The southern advance of the Arctic front in October places the area under the influence of the cooler, dry Arctic air until the front retreats north in early June.

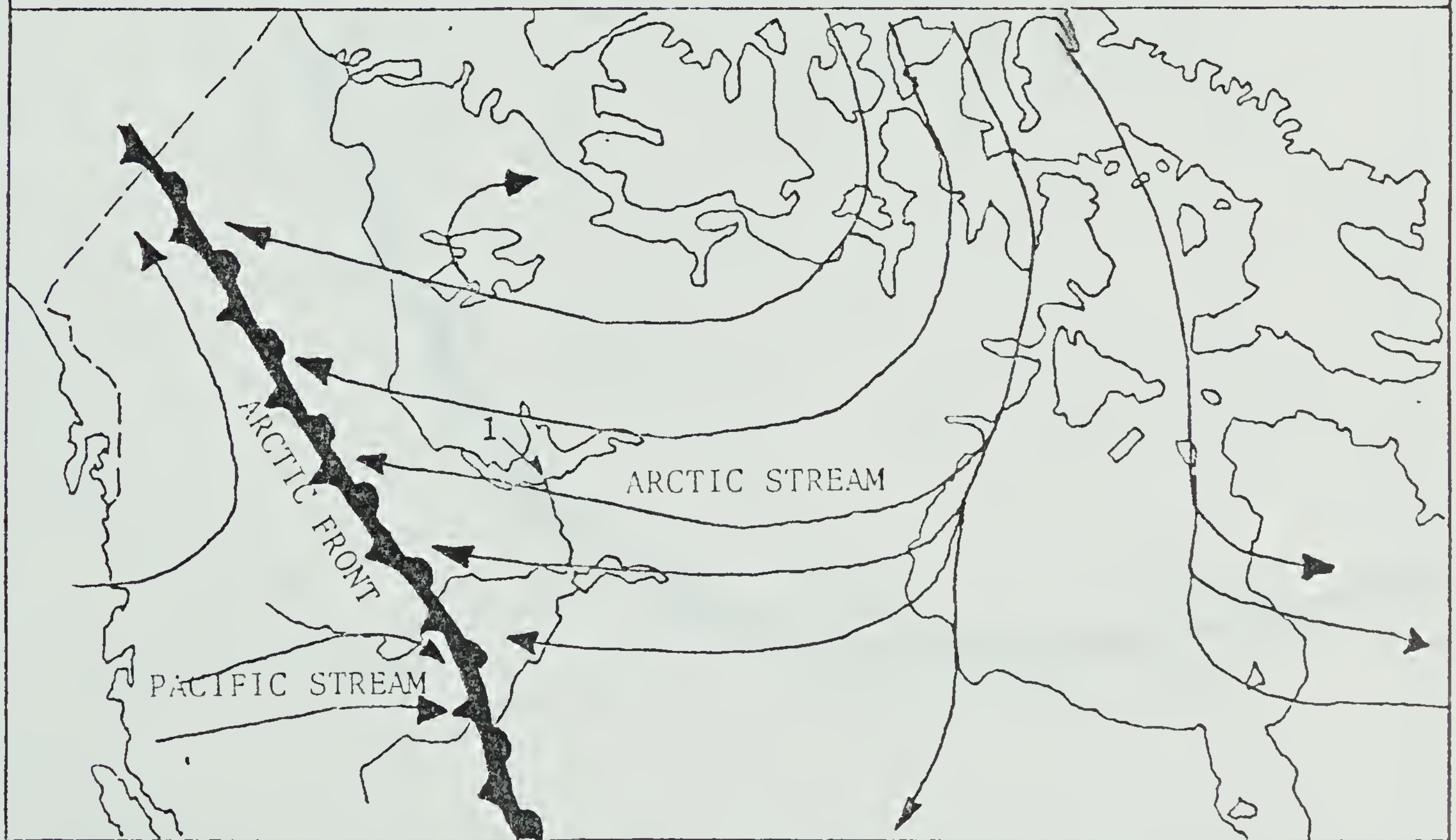
2.7 Soils

The soils of the Slave River Lowlands, including the Slave River Delta, are classified by Agriculture Canada (1974) as Humic Gleysols. The lowlands are largely composed of alluvial parent material deposited over the last several thousand years. This area is divided into two Great Soil sub-groups: Orthic Humic Gleysols, associated chiefly with areas rarely experiencing flooding, and Cumulic Regosols, associated with areas inundated during the spring flood.

In a comprehensive soil survey of the Slave Lowlands, Day (1972) classifies the delta soils as mainly Cumulic Regosols. Figure 2.9 describes what Day (1972) terms a typical Regosol based on a soil profile from a site northwest of Sawmill Channel on the delta. North of Nagle Channel patches of Rego Humic Gleysols and Cryic Cumulic Regosols are found in the white spruce (*Picea glauca*) assemblages. Figure 2.10 illustrates the location and areal extent of these soil subgroups on the Slave Delta.



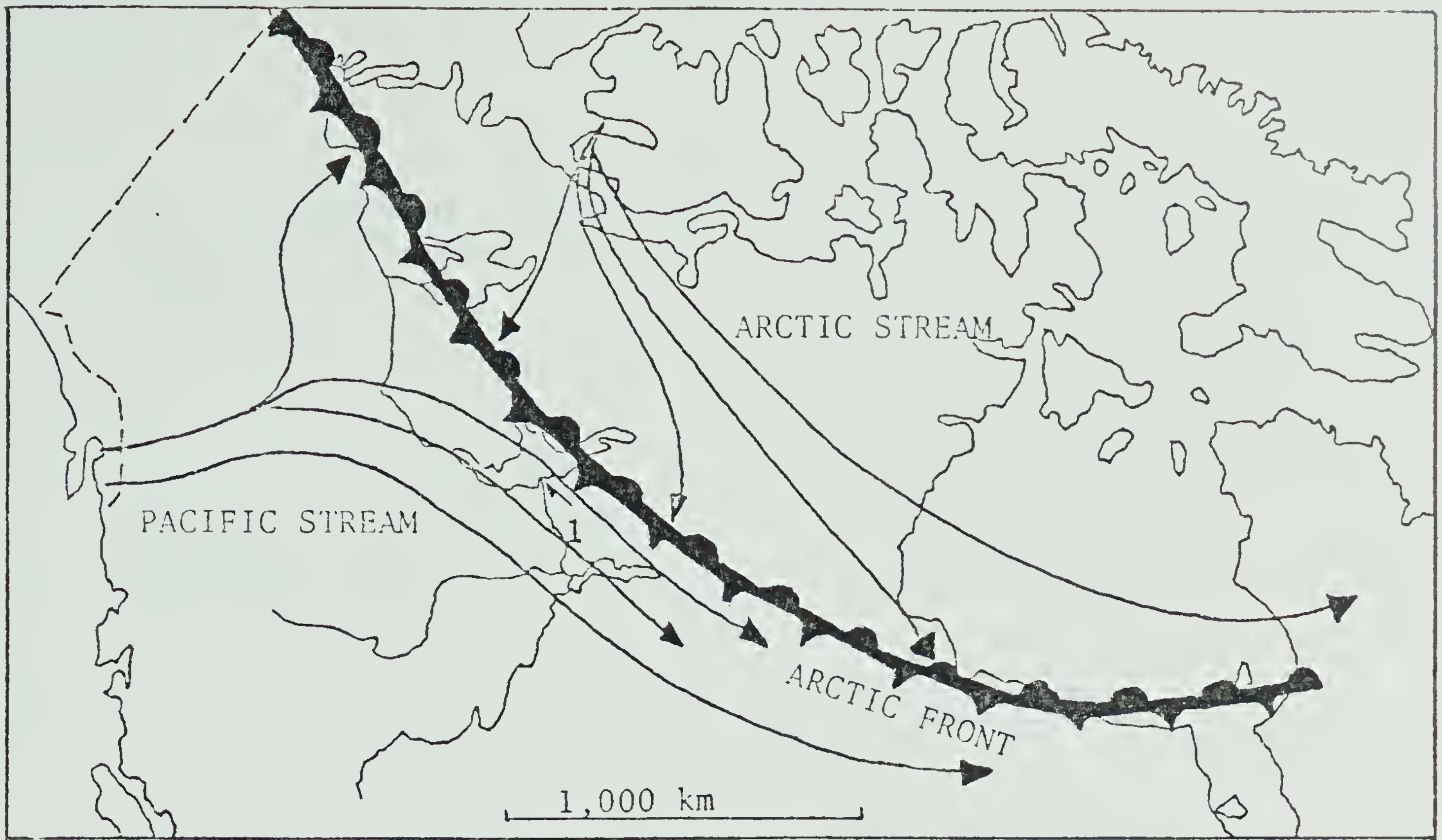
January



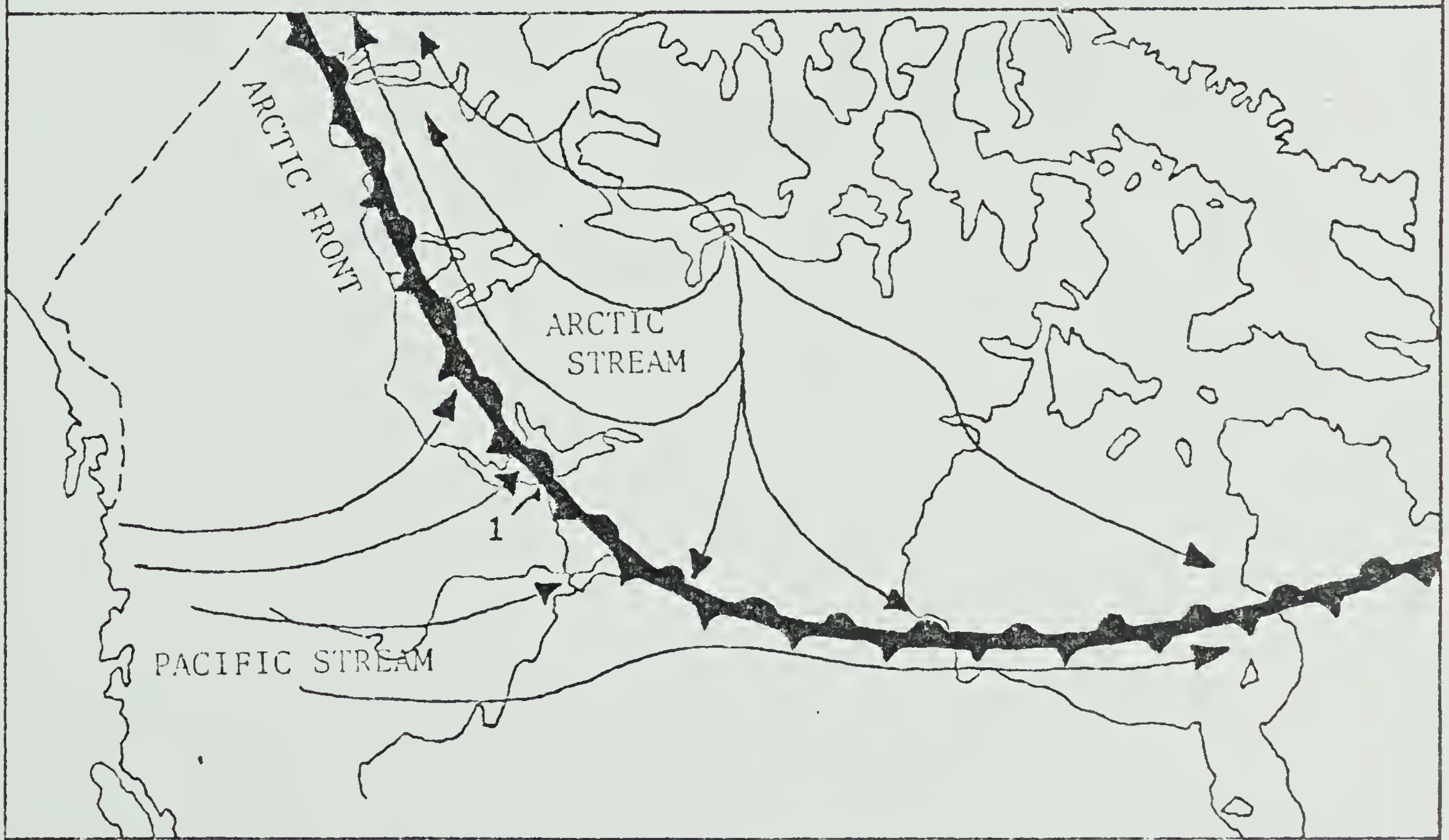
April

Figure 2.7: Position of Arctic Front, January and April.

(Hare, 1973)



July



October

Figure 2.8: Position of Arctic Front, July and October.

(Hare, 1973)

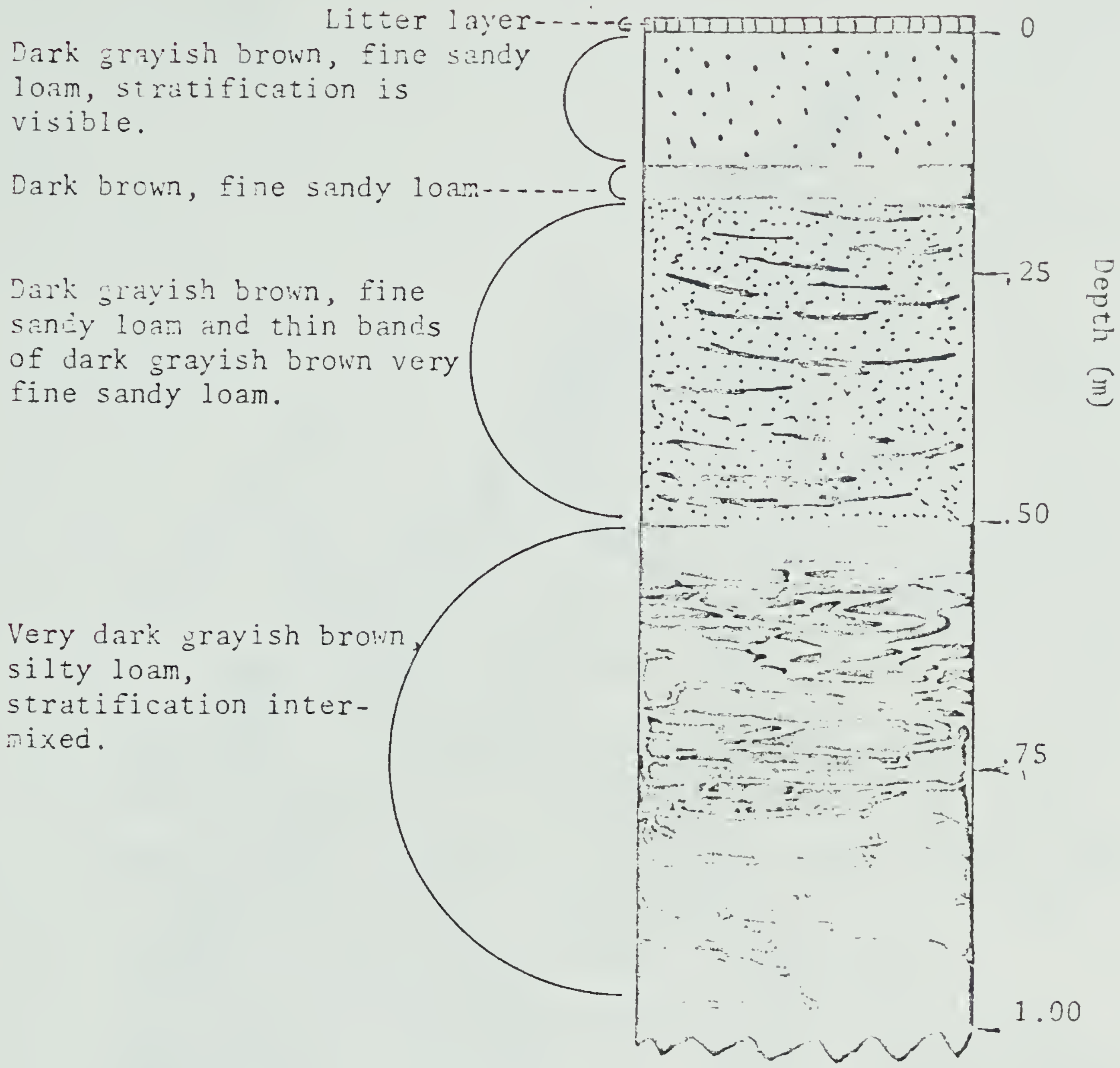
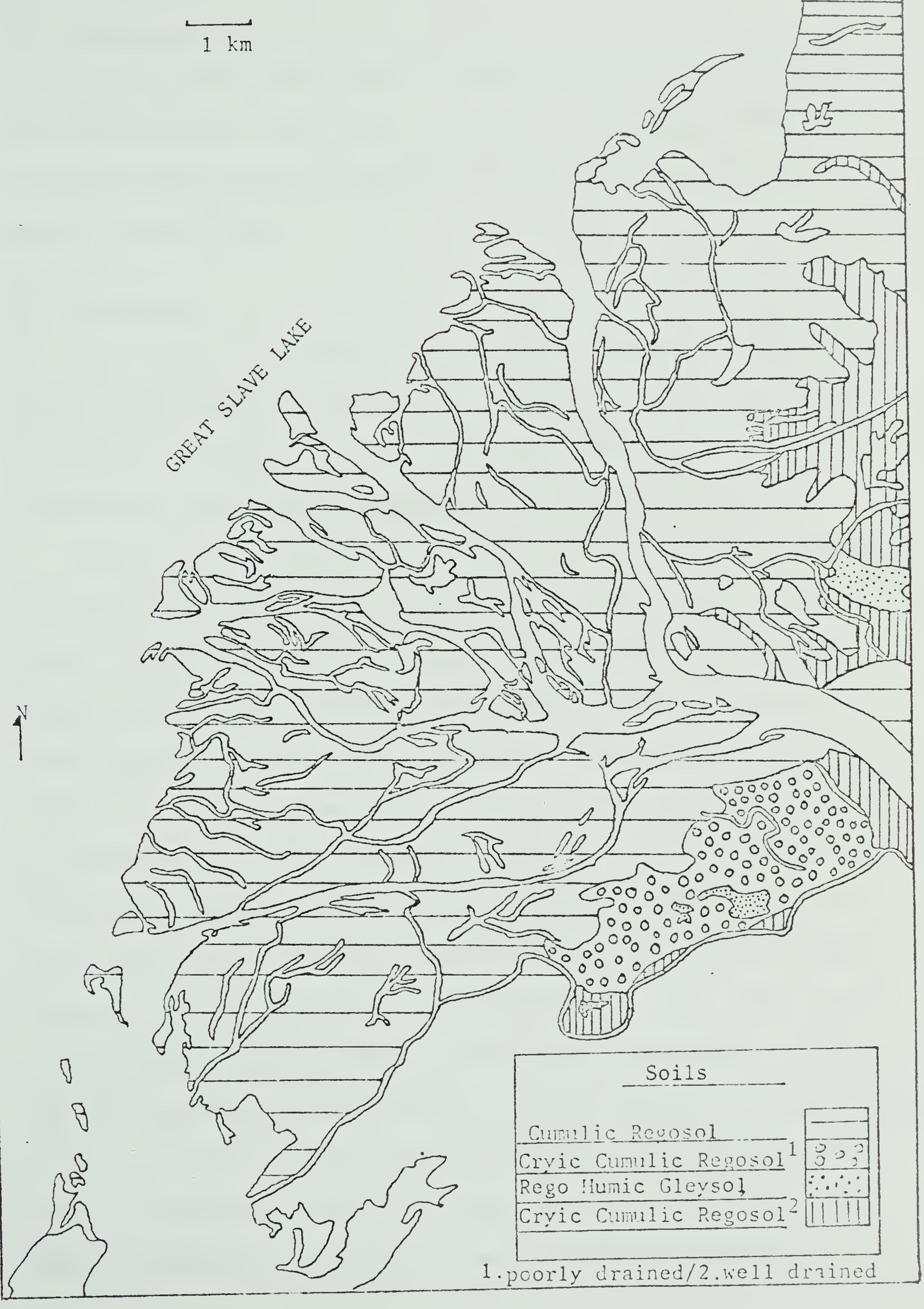


Figure 2.9: Typical Cumulic Regosol (Day, 1972)

Figure 2.10: Soil map, Slave River Delta. (Day, 1972)



2.8 Permafrost

The study area lies within the zone of discontinuous permafrost as defined by Brown (1960, 1971). Day (1972) identifies permafrost within the white spruce assemblages on the Slave Delta immediately north of Nagle Channel.

2.9 Vegetation

Rowe (1972) classifies the Slave River Lowlands as Forest Region B.23a, Upper Mackenzie Boreal Forest. Both Rowe (1972) and Day (1972) describe large expanses of white spruce and balsam poplar (*Populus balsamifera*) inhabiting alluvial flats along the Slave Lowlands.

The dominant soil group on the delta, Cumulic Regosol, is associated with willow (*Salix* spp.), alder (*Alnus tenuifolia*) and balsam poplar, with an understory of red osier dogwood (*Cornus stolonifera*), rose (*Rosa acicularis*) and horsetail (*Equisetum* spp.). The Iche soil group (composed of Cryic Cumulic Regosols) is found in areas immediately north of Nagle Channel (Day, 1972). Large white spruce, alder and balsam poplar, and an understory of rose, red osier dogwood, horsetail, and wintergreen (*Pyrola* spp.) are associated with the Iche soil group. The vegetation pattern associated with the Jerome soil group (composed of well drained Cryic Cumulic Regosols - Day, 1972) consists of white spruce, balsam poplar and alder, and an understory of rose, high bush cranberry (*Viburnum edule*), fireweed (*Epilobium angustifolium*), horsetail, bearberry (*Arctostaphylos uva-ursi*), red osier dogwood and mosses. The organic rich Taltson soils (Rego Gleysols - Day, 1972) found in isolated patches north of Nagle Channel are dominated by

sedges (especially *Carex aquatilis*), grasses, and a sparse cover of willow.

2.10 Fort Resolution

The village of Fort Resolution is located on Great Slave Lake near the south edge of the Slave Delta. In 1785 Laurent Leroux established this settlement as a fur trading post for the North West Company. Fort Resolution remained a significant northern community in terms of economics and education until the Slave River diminished in importance as a major northern transportation artery (Smith, 1975).

Since the establishment of Fort Resolution, the Slave Delta has been of prime economic importance to the settlement. As many as 46,000 muskrats have been harvested from the delta area during good years (Law, 1950; Bodden, 1979). The delta remains important to local residents as a substantial portion of their income continues to be derived from muskrat fur. Other species of animals, notably beaver, lynx, black bear, moose, snowshoe hare, and waterfowl, provide fur and country food for the people of Fort Resolution.

Historically, the large white spruce stands north of Nagle Channel were selectively harvested for the commercial production of rough cut lumber at sawmills built on the delta and in the village.

A complete economic picture of Fort Resolution and its dependence upon the delta for furs, country food and timber production is given by Smith (1972) and Bodden (1979).

CHAPTER THREE

METHODOLOGY

3.1 Pre-field season

Preliminary evaluation of plant assemblage distribution on the Slave River Delta was accomplished by constructing a base map from an aerial photograph mosaic. The panchromatic black and white mosaic of the delta was produced for this project by the Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa. From this mosaic, cartography technicians of the Department of Geography at The University of Alberta drafted a base outline map of the delta at a scale of 1:19500. By employing the electronic planimeter at the Alberta Remote Sensing Centre, I calculated the dimensions of the delta from the base map. Calculations included the lengths of all major and minor distributaries, length of shoreline, and the areal extent of each island.

Pre-field mapping of plant distribution included intensive interpretation of 1973 black and white panchromatic aerial transparent photographs. A plant assemblage map was drawn by incorporating techniques involving density slicing and stereoscopic interpretation.

The available aerial photography had limitations for interpreting plant communities. The scale of the photography, 1:26,073, made it difficult to identify even the dominant vegetation by species. This problem was recognized by Heller *et al.* (1964:2):

> "Forest photo interpreters have recognized for some time their inability to identify images of individual tree species on small scale photographs (1:15,850 or smaller)"

The limitations of black and white panchromatic film for aerial interpretation of vegetation are also well recognized (Kuchler, 1967; Haavisto and Jeglum, 1973; Meuller-Dombois and Ellenberg, 1974).

In 1966, the Canadian Department of Agriculture surveyed the Slave River Lowlands (but excluded the Slave Delta), using both colour and black and white aerial photography. They found that "the vegetational differences are more distinctive in colour than in black and white" (Reeves, 1975:444). Black and white photography limits the interpretor to determining differences between tones of grey and texture. Heller *et al.* (1964) report that the eye can separate 200 tones of grey whereas it can distinguish 20000 hues and chromas. As there are limitations when using black and white photography for terrestrial and wetland plant identification (Thie, 1972; Dirschl and Dabbs, 1972), the density slicer at the Alberta Remote Sensing Centre was used to enhance the grey tones of the aerial imagery.

On the density slicer, the black and white transparencies are scanned by a television camera which projects the image through a cathode ray tube and converts the numerous image densities to voltages (Lintz and Simonett, 1976). Using a keyboard panel, various voltages or densities may be sliced out of, or added to, the projected image. The conversion from various tones of grey in the original photograph to a colour version on the television screen of the density slicer was recorded using a 35 mm Pentax Spotmatic F camera loaded with Ektachrome 64 asa film. The entire delta was recorded on film in this manner. By slicing out the same densities for all transparencies, the plotting of plant communities was much easier. For instance,

white spruce was expressed in the same colour on the television screen image of each aerial photograph, and therefore was readily recognized in the photographs recorded by camera.

Certain areas of the delta were examined in greater detail by employing the zoom lens on the television camera of the density slicer. The distribution of aquatic and semi-aquatic plant species in the delta is contagious and has little recurring pattern, forming a heterogeneous assemblage which is very difficult to map if aerial photography is not used.

The slides of the density sliced images were projected onto a glass sheet at the base map scale of 1:19,500. These images were traced on paper and then transferred onto the base map.

The images produced by the density slicer were very useful for dividing the delta into vegetation types, but certain problems were recognized. This machine analyzes densities (or degrees of spectral reflection) on photo transparencies such that a body of water may have the same colour on the television screen as a stand of spruce. This also occurred many times between dissimilar species. The original photographs therefore had to be compared with the enhanced density sliced images when tracing vegetation zones on the final map so that mistakes created by mechanical misinterpretation could be identified.

The completed map made it possible to conduct an office study of vegetation distribution and plant community patterns in relation to channel morphology.

3.2 Field seasons

The 1977 field season began 12 May and ended 21 August. During the first week, a meeting was held with the people of Fort Resolution to inform them of the study. The Settlement Council unanimously approved the study. In accordance with the science policy of the Northwest Territorial Government, and out of respect for the local community, the Settlement Council was informed monthly of our progress. The first two weeks of the 1977 field season involved extensive foot transects and lengthy canoe trips along every channel in the delta to become thoroughly familiar with the study area. Detailed notes were taken on geomorphological features, plant assemblages, driftwood accumulation and various interrelationships among these and other parameters.

The 1978 field season consisted of a brief visit to the delta (26 April - 3 May) to measure snow density, water equivalence and depth of the snowpack in selected plant assemblages. Observations were also made on the formation of ice along portions of the outer delta.

3.2.1 Transect surveys

Eighteen transects were cut and surveyed during the 1977 field season (Figure 3.1) in order to establish elevations of various alluvial landforms relative to water level of the Slave River. Surveying these transects provided an accurate base on which to plot the linear extent of various plant assemblages.

The transects were selected so that a representative range

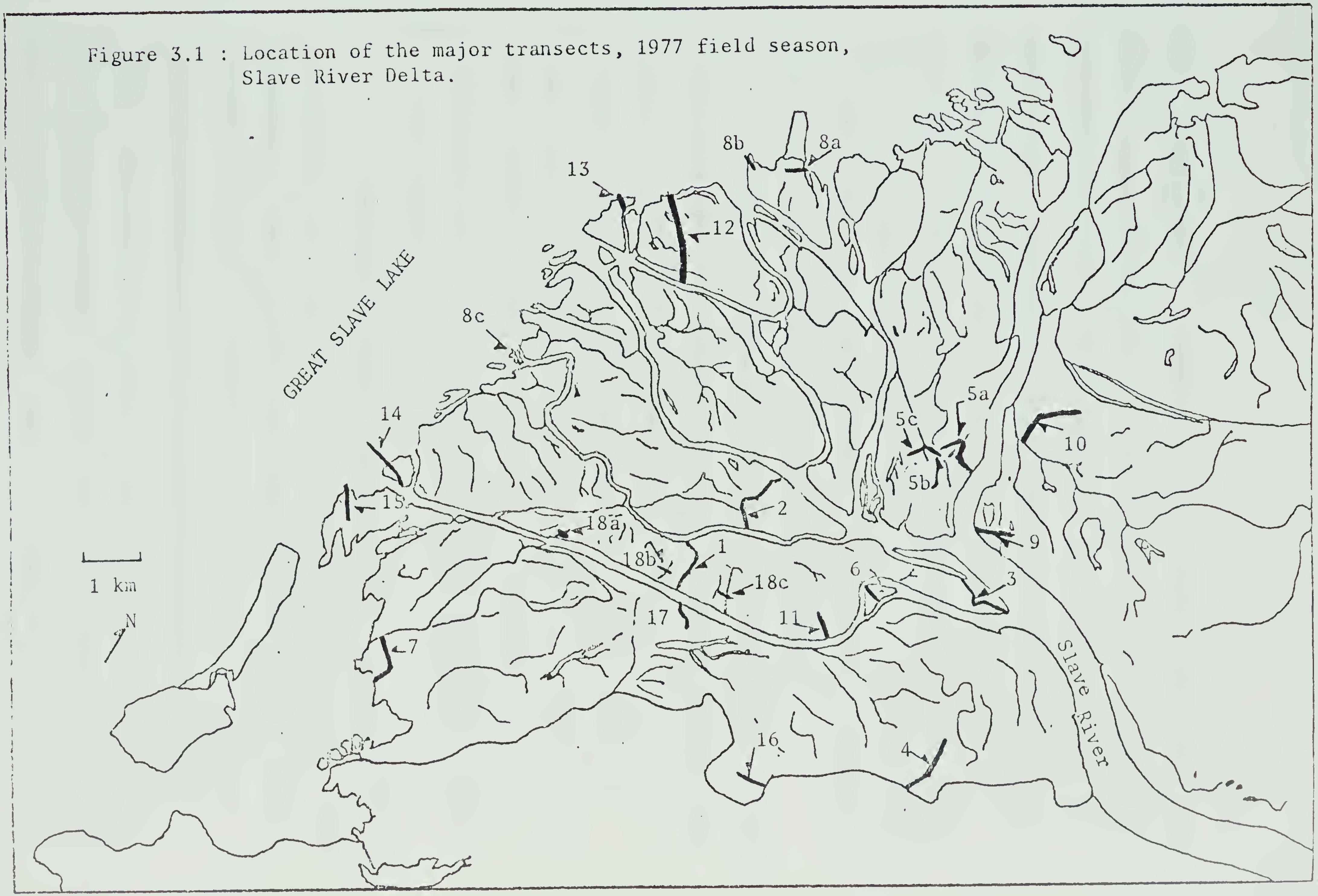


Figure 3.1 : Location of the major transects, 1977 field season, Slave River Delta.

of plant assemblages at different stages of successional development could be studied, and the relationships between vegetation and the physical environment could be established. The technique used to survey these transects was a simple open traverse employing the differences in elevation calculation of Bouchard and Moffitt (1972: 421) and Puch (1975:18). The datum for each transect was the water level of the Slave River (or Great Slave Lake - depending upon which area of the delta was being examined) at date of survey. Maximum level of the spring flood was recorded where possible.

Transects located in the aquatic and semi-aquatic expanses of the outer delta were surveyed by using the standard dryland technique wherever the footing was stable and water was not too deep to be waded. Along portions of transects where the water depth was greater than approximately .30 m and the bottom was composed of unstable sediments, the bed configuration was determined by recording water depths every 25 m along the transect with the use of a canoe.

3.2.2 Sample plots

Along each transect, sample plots were located in different plant assemblages. One of the primary objectives was to analyze the vegetation by employing the Braun-Blanquet (1932) technique, thus the plots were established in a representative position within each assemblage so that the transition areas along the borders were excluded. The criteria of Mueller-Dombois and Ellenberg (1974:46) were met in each plot; namely, the sample stand was large enough to contain all species belonging to the plant community, the habitat was

uniform within the stand area, and the plant cover was as homogeneous as possible. The average plot size for assemblage analysis was 400 m^2, but varied in size depending upon the type of plant assemblage being studied. In areas of the outer delta occupied by large expanses of *Equisetum*, a 2500 m^2 plot size was used.

Eighty-five plots were studied along the transects and 4 additional plots were located in other sites where fire and logging disturbances warranted investigation. In addition to vegetation analysis, at each plot the following environmental factors were investigated: soil profiles, alluvial geomorphology, surface micro-relief, the degree of exposure to the wind, presence or absence of permafrost, frequency of flooding, and soil moisture class.

3.2.3 Vegetation

In the field, identification and selection of plant assemblages for analysis posed little problem. In some instances where identification of boundaries between assemblages proved difficult, this was aided by the preliminary map and aerial photographs.

Vegetation analysis for most plots was accomplished using a modification of the Braun-Blanquet system (Gill, 1971). The following measurements were made in each plot: species significance, sociability, vigour and periodicity.

Species significance (Mueller-Dombois and Ellenberg, 1974: 60) was evaluated qualitatively in the majority of plots by visually estimating its percent coverage in proportion to other species in the plot. However, the *Equisetum* plots in the outer delta were sampled

for species composition by clipping all plants within a 1 m^2 area. Table 3.1 illustrates the numerical values assigned for species significance and percent cover-abundance.

Table 3.1: Species significance scale showing cover-abundance for each numerical rank

Ranking	Species significance	
	Qualitative value	Cover-abundance (%)
1	Rare occurrence	Negligible
2	Seldom occurring	up to 5
3	Common occurrence	6 - 10
4	Occurring often	11 - 20
5	Occurring very often	21 - 35
6	Abundant cover	36 - 50
7	More abundant	51 - 75
8	Very abundant	up to 95
9	Most abundant	96 - 100

The evaluation of sociability is an evaluation of dispersion of a species within a sample plot. Table 3.2 assigns numerical values to the varying distributions of species within the sample plot.

Table 3.2: Sociability Index

1	Growing singly
2	Grouped or tufted
3	Growing in small patches or cushions
4	Growing in small colonies, extensive patches, or forming carpet
5	Forming pure populations

The vigour of a plant species is assigned a value as shown in Table 3.3.

Table 3.3: Vigour Index

0	Dead
1	Dying, not successful
2	Poor vigour, barely successful in setting seed
3	Good vigour, successful, abundant seed
4	Excellent vigour, most successful in assemblage

The periodicity or stage of plant growth is illustrated in Table 3.4.

Table 3.4: Periodicity Index

1	Budding
2	In foliage
3	Leaf fall
4	Leafless
5	Flowering
6	Fruiting
7	Seedlings

A structural profile of each releve was assessed by using an analysis sheet upon which the corresponding numerical values for species significance, sociability, vigour and periodicity were noted, together with relevant environmental information.

Phenology of plant species varied depending upon individual physiology and physical location on the delta. Microclimate plays a large role in determining plant phenology. For example, open, exposed sites on the outer delta create harsh environmental conditions, causing plants of the same species to flower later here than in areas near the apex of the delta. Phenology therefore played a role in the timing of the fieldwork; vegetation in the interior part of the delta was sampled in late June and early July, while the outer delta was sampled during late July and early August.

Although timing of the sampling aided in field identification of species, some plants had not reached flowering stage at the time of sampling. Thus such plots had to be revisited later in the season.

Plots bordering Great Slave Lake, where driftwood plays an important role in shoreline stabilization, were evaluated for vegetation structure by mapping 1 m wide strips perpendicular to the shore. In several instances (such as transect 6, plot 1 - Figure 3.1), plots were located on the lakeshore to enable the analysis of littoral plant succession.

DBH, height and age were measured for the tree stratum in all plots. Age was determined by employing a Swedish increment borer and counting the annual rings. In each of the climax white spruce plots, one tree was cut down to compare the full annual ring count with ages taken from the increment cores. This also allowed a more accurate measurement of tree height in the denser stands. Aging of

trees and shrubs proved valuable in estimating the minimum age of the alluvial feature upon which an assemblage was growing.

3.2.4 Plant collection

Plants were collected throughout the field season, during the flowering stage whenever possible. Tentative identification was made in the field or at base camp, followed by pressing and drying after the methods given by the U.S. Forest Service (1974).

3.2.5 Soil pits

Soil pits were dug at each plot and in other locations along transects so that a contiguous series of soil profiles could be studied. Each pit was dug to frozen ground or free water, and the thickness of sediment and organic layers was measured downward. A soil temperature profile was recorded at 5.0 cm intervals by using a 95.0 cm YSI 419 temperature probe attached to a YSI Model 425c Telethermometer.

Samples were collected from the different soil layers and preserved in plastic bags for future laboratory analysis. These samples were weighed on a 2610 g capacity Soiltest triple beam balance at base camp the day they were collected.

3.2.6 Seasonal frost and permafrost

Depth to frost was measured whenever encountered. Frost that was still in the ground by late August was classed as permafrost. Depth to permafrost was measured every 5 m along several transects so that an accurate profile could be established.

Transects 1-4, 9, 10, 12 and 16 (Figure 3.1), all under-

lain by permafrost, were sampled for active layer depth using a 95 cm metal probe. The plant cover present where permafrost occurred was noted to determine if a correlation exists between vegetation and permafrost distribution.

In areas of hummocky topography (due chiefly to fluvial erosion), such as on transects 1 and 9 (Figure 3.1), the depth to permafrost was measured to evaluate the effects of microtopography on active layer depths.

Permafrost is widespread in the white spruce climax assemblages north of Nagle Channel. Several transects were surveyed perpendicular to transect 4 (Figure 3.1) and measured for active layer depths. Three pits averaging 60 cm deep were dug into the permafrost to obtain samples for laboratory analysis. The topography of the permafrost table around tree stems was evaluated by running 3 m transects out from the base of several trees in the four cardinal directions. Active layer depths were then sampled at 0.5 m intervals along each transect.

Thermokarst erosion was noted in only one location on the delta, in a white spruce assemblage along Little Jean River.

3.2.7 Evaluation of historical flood levels

Relative changes in water levels were recorded weekly from 30 May to 20 August 1977. This was accomplished by installing a ruled 3.5 cm diameter dowl in 20 cm of water across from the base camp on Steamboat Channel. Water levels and volume of flow in the Slave River from 1954 to 1977 were provided by the Water Survey of Canada

(1977).

In order to relate the historical flood levels to the surveyed transects, the water level surveyed at each transect was compared the same day to the water level on the river dowl. Historical water levels at a particular transect could then be extrapolated by referring to the records for the years available.

Soil pit excavation aided in determining the flood history of the delta. Periods of low water level enable organic litter to accumulate on the ground surface in the terrestrial portions of the delta. Flooding then results in the burial of this litter by a layer of sediment devoid of organic matter. The alternating layers of litter - sediment - litter were observed in the majority of soil pits.

3.2.8 Suspended sediment

Suspended sediment data for the Slave River was provided by the Water Survey of Canada (1977). Deposition of suspended sediment was sampled weekly at three locations by placing aluminum pans along the shallow beds of selected water bodies. Three pans were placed across from the base camp on the submerged portion of a sand bar. One pan was placed on a developing point bar at Four Ways (Figure 4.21), and one was placed at the junction of Four Ways Channel and Steamboat Channel. The annual deposition of sediment was also measured by projecting a probe into an alluvial bar until resistance was encountered. The alluminum around the probe was then excavated until the layer of resistance was exposed. This layer was usually found to be different from the surface alluvium either due to different

conditions of sedimentation during the previous spring, or being formed by the previous year's buried vegetation. This method gave a fairly accurate assessment of the amount of sediment deposited during and since the 1977 flood stage in two locations. Portions of the outer delta were measured in the same manner, but the complex and rapidly growing rooting system of *Equisetum* made it impossible to determine a clear boundary between the 1977 and previous year's sediment deposits.

A secchi disc (Ruttner, 1975) was employed to illustrate the relative turbidity between various water bodies on given dates.

3.2.9 Channel sedimentation

Three channels on Mouse Island (Figure 4.37) were investigated to compare the closure of channels through sedimentation. One channel is still open to Steamboat Channel, one has been recently closed off, and the third has been closed off for a number of years. The standard assessment of vegetation along levees was implemented, together with an analysis of aquatic vegetation. Soils, permafrost, secchi disc values, and channel depths were also noted. Several additional transects bisected old channels and the information collected at each was synthesized to relate channel closure to change in plant community development.

3.2.10 Snowpack sampling

Between 26 April and 3 May 1978, the snowpack in selected plant assemblages was sampled for snow depth, density and water equivalence. A Mount Rose sampler was employed, using the method

described by Adams and Barr (1974). Observations and measurements were made of plant clones and ice and snow formation along portions of the outer delta.

3.3 Post-field season

3.3.1 Vegetation map

True colour and colour near infrared aerial photography of the delta was flown at a scale of 1:23,854 by the Canadian Wildlife Service on 7 September 1977 at the end of the field season. This photography coupled with three months of prior ground truthing, proved extremely valuable in refining the vegetation map of the delta. There were three valuable results from photographing the delta at this time. First, fieldwork had just been completed so the photography represented a current record of the vegetation studied during 1977. Secondly, most of the transects cut during the field season were readily observed in the new photography greatly assisting in relating previous groundwork to the colour and texture of plant assemblages recorded by the photographs. Thirdly, the leaves of balsam poplar and most willow species had turned colour by early September, enhancing the difference between these and other species whose colour had not yet changed, thus further aiding identification. These advantages helped to overcome any problems created by the small scale of the photography.

The Delta 4 distortion on the sides of the photographs (Reeves, 1975) was taken into account during final drafting of the

plant assemblages. As there was a 60% overlap of flight lines, only the centre portions of the photographs were used for delineating plant assemblages. Most of the tracing of plant assemblages was done on a Zeiss-Jena Interpskop at the Alberta Remote Sensing Centre. This instrument provides the opportunity for viewing the photographs stereoscopically and at the same time enlarging the image to focus on detail. Transferring the tracings of vegetation boundaries to the base map was done using a Keuffel and Esser Kargle Reflecting Projector at The University of Alberta's Department of Geography Cartography Laboratory.

The map resulting from this interpretation identifies 11 plant assemblages.

3.3.2 Verification of plant species

The vascular plant collection was taken to the Herbarium of the Northern Forest Research Centre, Canadian Forestry Service, Edmonton, where verification of species was done by Mr. J.D. Johnson, Assistant Curator. Bryophytes collected in the field were identified by Mrs. Catherine England. A systematic tabulation of species was then composed. The voucher collection is held by Dr. Don Gill of the Department of Geography, The University of Alberta. A duplicate collection was deposited with the Herbarium of the Northern Forest Research Centre, Edmonton.

3.3.3 Soil analysis

3.3.3.1 Soil moisture

All soil samples were oven dried at 105°C for 24

hours and then reweighed for determination of soil moisture content.

3.3.3.2 Dry sieving

Evaluation of grain size greater than 4 ϕ was accomplished by following methods given in McKeague (1976). Each sample, previously oven dried, was mechanically crushed in a mortar using a rubber tipped pestle. The sample was then weighed and placed into a column of two sieves with 0 ϕ and 1 ϕ mesh. The sample was vibrated on a Tyler Model RX-24 Portable Sieve Shaker for 5 minutes so that a sample could be obtained for total organic carbon analysis at a later date. The Walkley-Black method for total organic carbon determination (Black, 1965) states that particle size less than 0 ϕ must be used. After a sample for total organic carbon determination was removed from the original sample, it was reweighed and placed in a second column of 2 ϕ, 2.5 ϕ, 3.25 ϕ, and 4 ϕ sieves and vibrated in the sieve shaker for 20 minutes. After dispersion, the contents of the sieves were weighed individually. A sample of the finer sediment from the catchment tray beneath the 4 ϕ sieve was removed for analysis in the cyclosizer.

3.3.3.3 Cyclosizing

The Warman Cyclosizer (subsieve sizer) Model M-4 was used to estimate the portions of the original sample ranging between 4.5 ϕ and 6.4 ϕ, from very fine sand to medium silt.

The disadvantage of this method is that the clays and fine silts are lost in the process. The advantage, however, is that the conditions governing the separation of the various grain sizes are controlled. Although temperature of the water varies from

one run to the next, this is recorded so that it can be applied to a correction factor.

3.3.3.4 Total organic carbon

Total organic carbon is indicative of the amount of organic material in soil (Black, 1965). By analyzing various layers of the soil profile for total organic carbon, some assumptions may be drawn regarding the flooding and vegetative history of a particular site. It is assumed that the longer an area remains flood-free, the greater will be the buildup of organic matter. The Walkley-Black method (Black, 1965) was used for total organic carbon determination.

3.3.3.5 pH

The pH of representative soil samples was measured in the lab following the standard method given by McKeague (1976). A Sargent-Welch model PBL pH meter was employed for all samples.

CHAPTER FOUR

PROCESSES

4.1 Flooding and spring breakup

Annual flooding occurs in the large expanses of *Equisetum* and *Carex* marshes found along the distal portions of the Slave Delta. The levees in the outer delta are immature and the mean elevation of those surveyed is approximately 0.05 m above the August 1977 water level of Great Slave Lake. A large number of these levees do not extend above the water level of the lake throughout the summer months (Figures 4.1 - 4.3[1]).

Since the Slave River provides at least 80% of the water volume of Great Slave Lake (Bennett, 1973), previous high spring flood levels on the delta can be calculated with some accuracy by employing the relationship between the mean monthly discharge of the Slave River and the mean monthly elevation of lake levels. Regression analysis of the discharge data from Slave River and corresponding levels of Great Slave Lake for 1969-71 yields a very significant correlation coefficient of $r = 0.87$ ($p = 0.005$; $n = 35$; Figure 4.4). By employing the linear regression equation describing this relationship ($y = 0.82 + 0.79 \times 10^{-4}X$), the mean discharge for a given month may be substituted for X and the corresponding mean monthly water level for Great Slave Lake can be computed. A valid criticism of this equation is that it was derived

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[1]The locations of transects are illustrated in Figure 3.1.

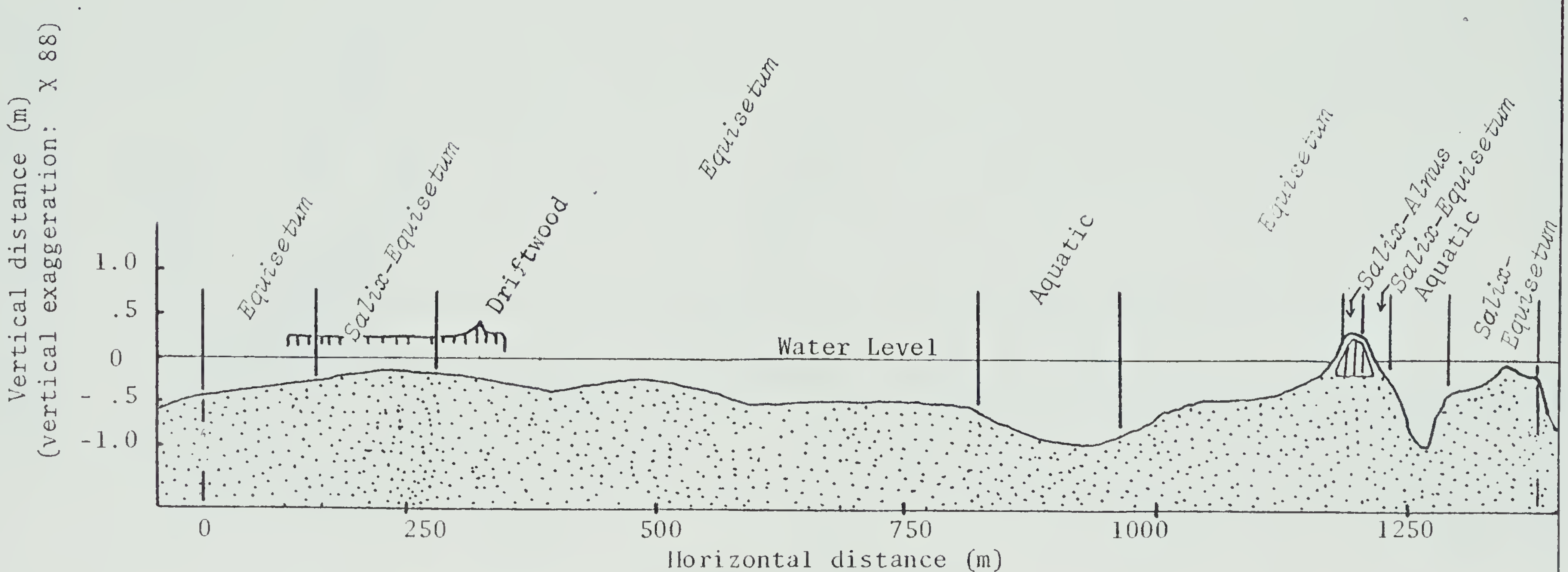


Figure 4.1: Transect 12, Plant Assemblages (sampled 15 July 1977).
Ground frost ( ) was found in the elevated levee.

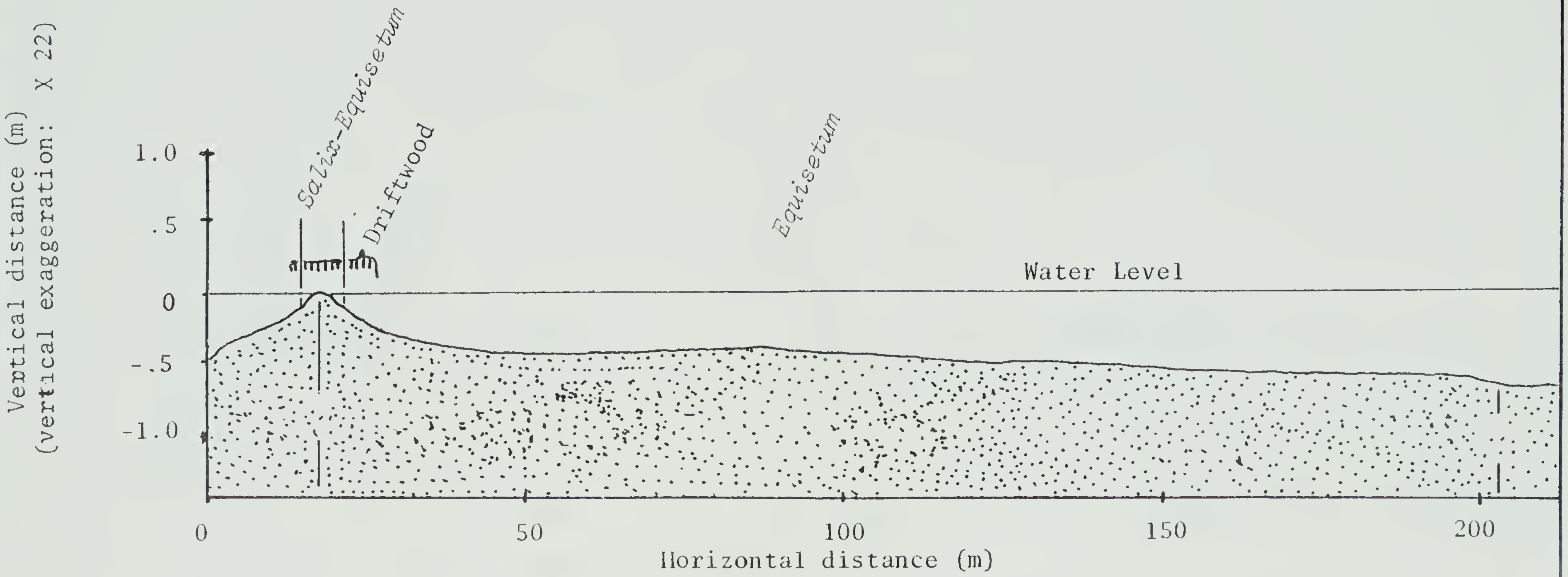


Figure 4.2: Transect 8A. Plant Assemblages (sampled 13 July 1977).

The *Equisetum* assemblage occupies the interlevee depression, inhabits the largely submarine levee, forming a portion of the outside border of a cleavage bar formation.

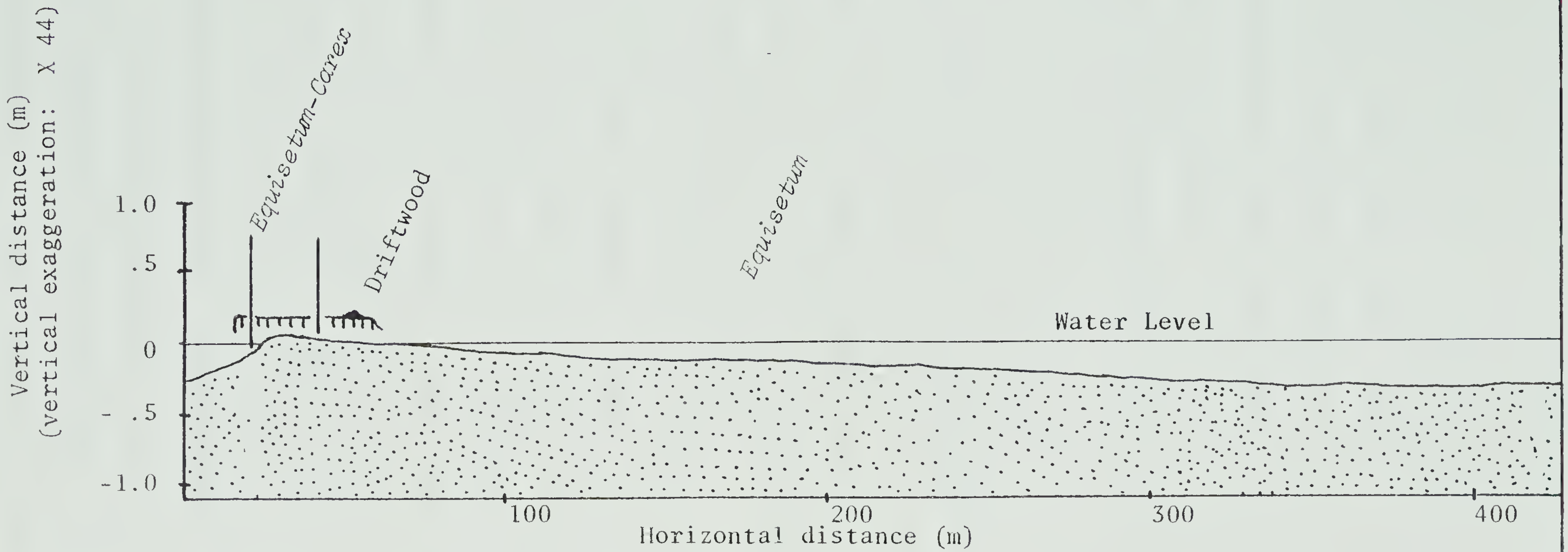


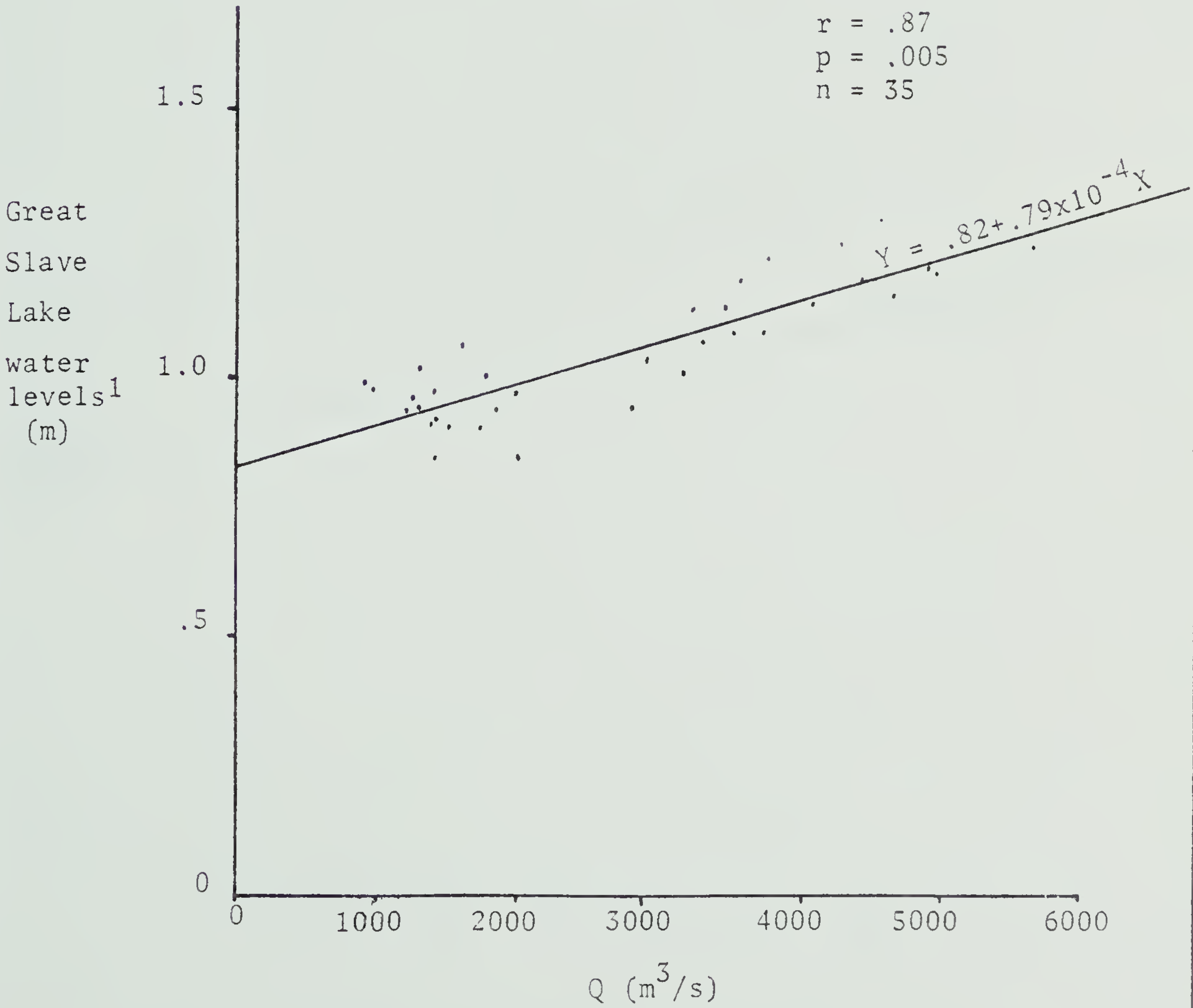
Figure 4.3: Transect 15. Plant Assemblages (sampled 17 July 1977).

Transect 15 illustrates the typical build up of the cleavage bar levees along the lake front, as driftwood aids in stabilizing the levees, encouraging accumulation of sediment.

from data representing only three years of hydrological relationships between the Slave River and Great Slave Lake. However, a similar relationship for the years 1964 through 1968 was derived and an equally significant relationship between mean monthly discharge and mean monthly water levels was achieved: $r = 0.68$ ($p = 0.005$; $n = 60$; Figure 4.5). Application of the equation describing the linear relationship during that 5 year period, $y = 1.12 + 0.52 \times 10^{-4}X$, results in a different set of values for flood height levels in the delta, given the same discharge used in the previous equation for 1969-71. This difference is illustrated in Table 4.1. The difference in values between August 1977 and June 1977 water levels is 0.08 m for the relationship derived from the 1969-71 data, and 0.04 m for the relationship derived from the earlier set of data.

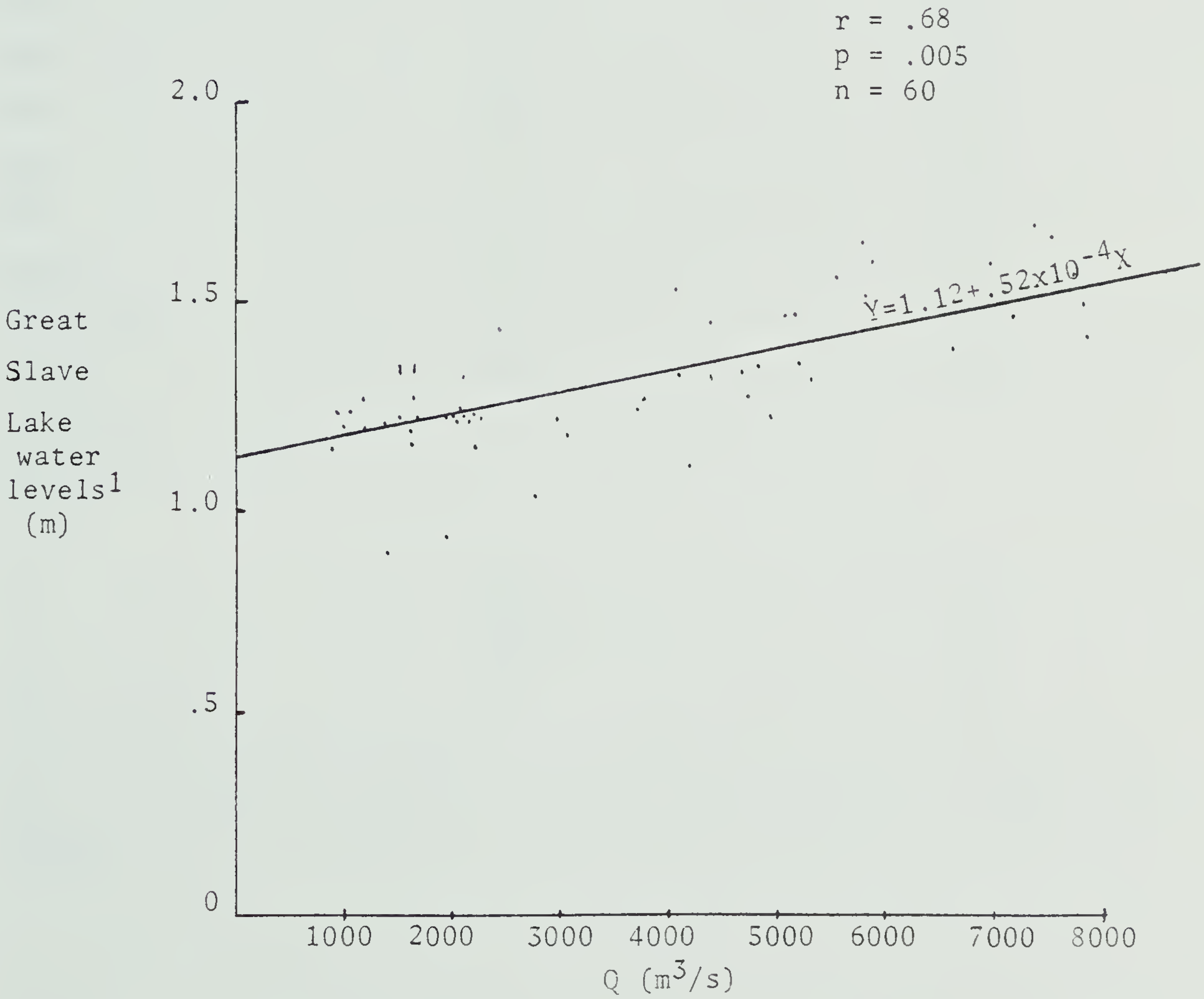
The differences can best be explained by the effect of the W.A.C. Bennett Dam on the Slave River's discharge. Kemper (1972) reports that construction of this dam has reduced the Slave's discharge. It is reasonable to assume that if the Slave River's discharge is reduced, its proportional contribution to the volume of Great Slave Lake may be likewise reduced as the other rivers supplying the lake have not been similarly affected by upstream impoundment. The 1964-68 discharge records employed in the previous equation are the result of natural river regimes in the Slave catchment prior to construction of the W.A.C. Bennett Dam. Post construction discharge records between 1969 and 1970 result from the regulation of the Peace River. An F-test (Freund, 1972) on the variances of the data described in Table 4.1

Figure 4.4: Relationship between Slave River Discharge and water levels in Great Slave Lake, 1969-1971.



1. Convert to G.S.C. Datum, add 155.1 m (a.s.l.)

Figure 4.5 : Relationship between Slave River Discharge and water levels in Great Slave Lake, 1964-1968.



1. Convert to G.S.C.Datum add 155.1m (a.s.l.)

Table 4.1: Differences in water levels employing the equations describing the relationships between the Slave River discharge and the water levels of Great Slave Lake.

1977 Monthly Mean Discharge	Equation derived from the relationship before Peace River impoundment $Y = 1.12 + .52 \times 10^{-4}X$	Equation derived from the relationship after Peace River impoundment $Y = .82 + .79 \times 10^{-4}$
January	1.27[1] m	1.05 m
February	1.27	1.05
March	1.25	1.01
April	1.26	1.04
May	1.38	1.21
June	1.43	1.30
July	1.42	1.27
August	1.38	1.22
September	1.33	1.14
October	1.34	1.15
November*		
December *		
$\bar{x}$	1.33	1.14
σ^2	.0046	.01
σ	.067	.10
*Data missing		

[1]The water level in metres is equated to Water Survey of Canada (1977) datum.

further shows that the two sets of data are significantly different and it is assumed that one of the major controlling factors governing the discharge of the Slave River during the two time periods is different. The other controlling factors would be differences in precipitation, timing of the precipitation and snowmelt, variation in lake evaporation and the effects of seiche. It is beyond the scope of this project to interrelate the various possible factors over the entire Slave catchment to determine exactly which climatic factors may have been different. Hare (1973) reports no major climatic change in northern Canada during the 1960's and early 1970's, but 1972 is generally reported as being a very cool year in the north. Since it appears that the climate over the eight year period 1964-1971 was relatively normal and the Peace River provides approximately 50% of the Slave's discharge (Bennett, 1973), it appears that impoundment of the Peace River played a key role in the different levels of Great Slave Lake.

Because current and future discharge of the Slave River will be a partial product of the regulated Peace River, the equation derived from the post-Bennett Dam records was used to relate mean monthly Slave River discharge to post-Bennett Dam flood levels in the Slave Delta. Pre-Bennett Dam flood history on the delta will be equated to the relationship derived from the 1964-1968 data. All flood levels will be derived from a common surveyed baseline - the mean August 1977 water level of Great Slave Lake as related to deltaic landforms (Figure 4.6 and 4.7).

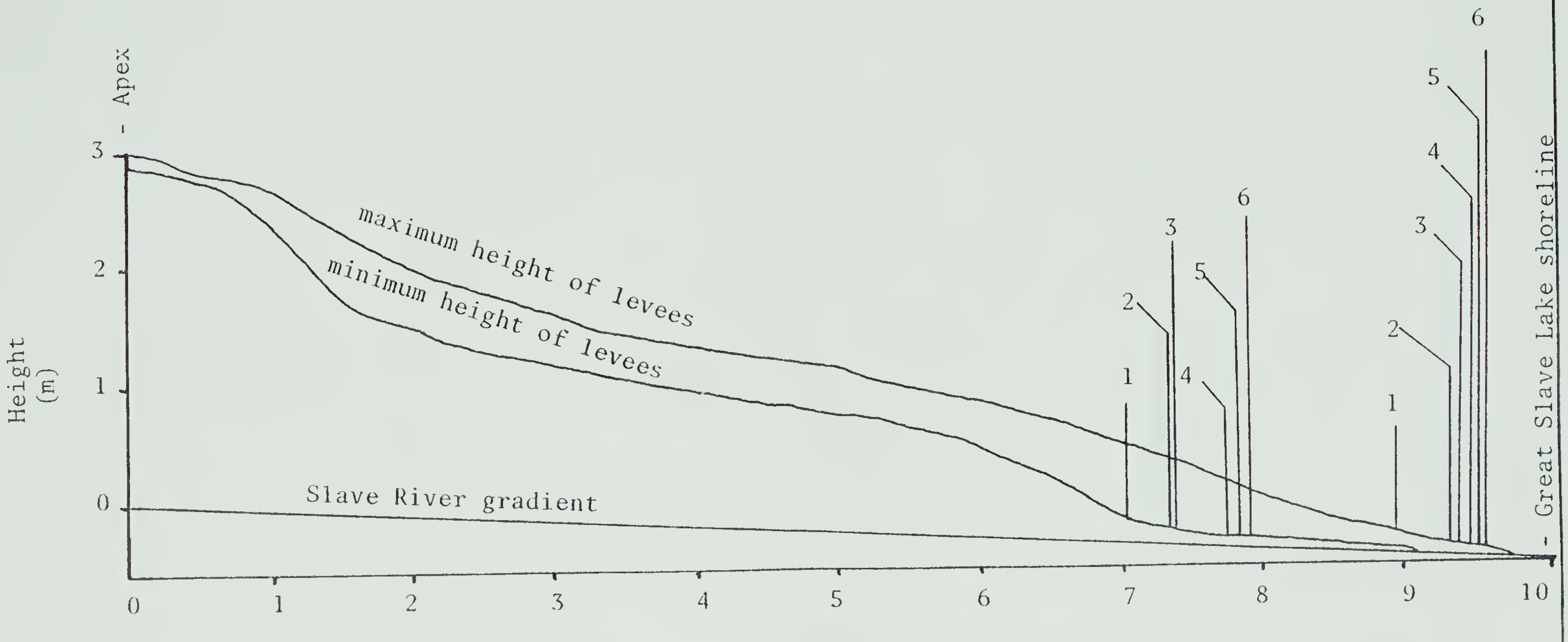
Figure 4.6 illustrates the maximum and minimum heights of levees above the mean August 1977 Slave River - Great Slave Lake water levels found in a straight line from the delta apex to the outer island formations. The gradient of the Slave River from the apex of the delta to the distal portions of the delta is included. Substituting the mean August 1977 discharge into the linear equation $y = 0.82 + 0.79 \times 10^{-4}X$, a water level value of 1.22 m is assigned to the mean water level of Great Slave Lake for August 1977[1].

From this baseline water level, the mean water levels for other months are plotted in Figure 4.6. Subsequently, the extent of the spring water levels in the delta can be approximated mathematically for years when ice damming did not occur in the delta. Incorporating the mean June 1977 discharge into the equation, a water level value of 1.3 m results, 0.08 m above the August water level. This is sufficient to flood 95% of the exposed zone of the outer delta and, at the very least, 75% of the protected zone (Section 4.4 defines the zones of the outer delta). As the gradient between Mountain Rapids and Great Slave Lake would remain proportionately the same, regardless of discharge a similar increase in water levels can be expected throughout the delta. The June 1977 discharge reached flood heights on developing islands and on elevated sand bars along the active distributaries of the delta. The flood height is defined as the maximum level the water reaches each year on the delta.

Figure 4.7 illustrates the maximum flood levels on the Slave Delta

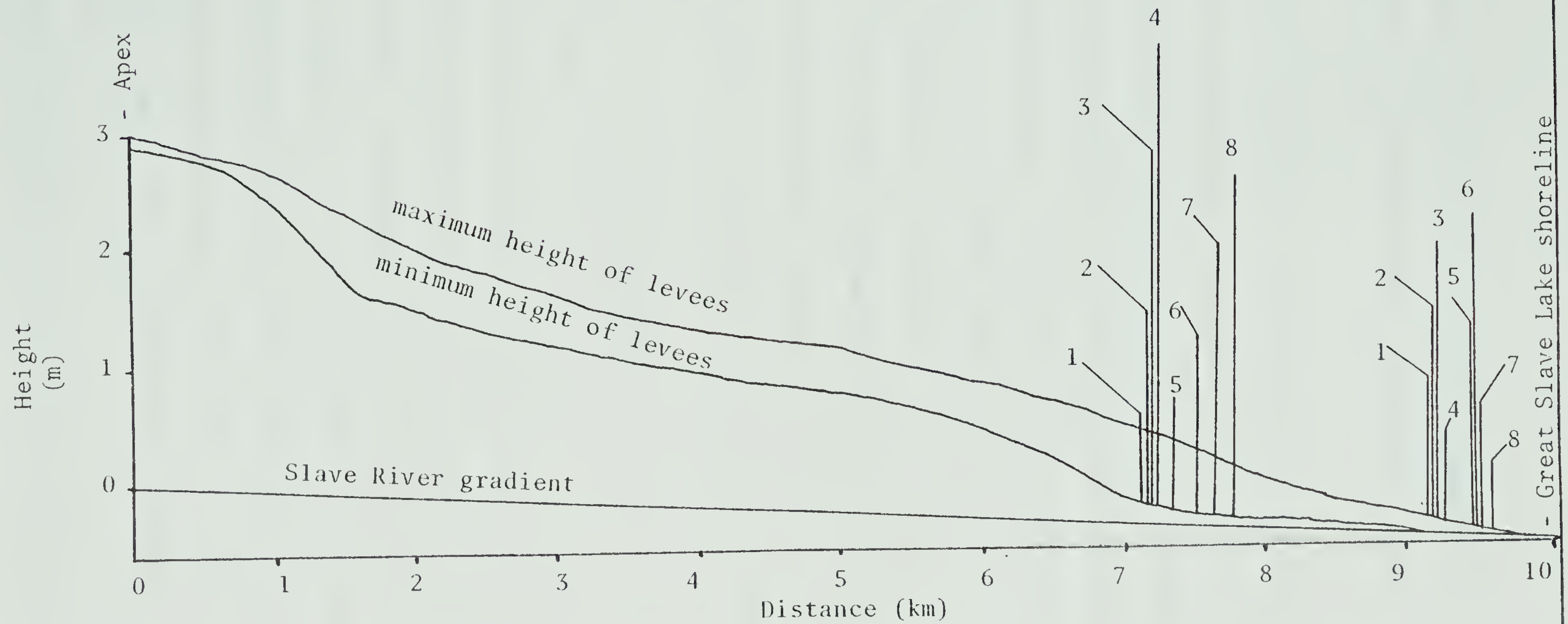
[1] To convert to the Geodetic Survey of Canada datum, add 155.10 m.

Figure 4.6 : Historical water levels on Slave River Delta, 1969-77 (inclusive).
Baseline river level - mean August 1977 water level (ice damming not taken into account).



Legend for historical water levels: 1, 1974; 2, 1972; 3, 1977; 4, 1976; 5, 1973; 6, 1971.

Figure 4.7: Historical water levels on Slave River Delta, prior to Peace River impoundment (1968). Baseline river level - mean August 1977 water level (ice damming not taken into account).



Legend for historical water levels: 1, 1921; 2, 1954, 1962, 1964, 1965, 1967; 3, 1963; 4, 1960; 5, 1961; 6, 1922, 1955; 7, 1966; 8, 1957.

prior to impoundment of the Peace River. It is interesting to note that the lake levels prior to the Peace River impoundment appear to have been higher.

Flooding of the *Picea glauca* stands located near the apex of the delta is infrequent as the levees along these channels are approximately 3.0 m above the mean August 1977 water level. The substantial bryophyte layer and presence of permafrost in these white spruce stands are evidence of infrequent flooding. According to local trappers the last flood which inundated these elevated portions of the delta was during the spring of 1935 (Beaulieu, Pers. Comm., 1977). Bennett (1973) and Raup (1975) mention this flood, but unfortunately discharge and water level data are not available for that year. In order to flood the levees at the delta apex, a mean monthly discharge of 37,000 m^3/s would be required:

$$y = 1.12 + .52 \times 10^{-4} (37,000)$$
$$= 3.04 \text{ m.}$$

This figure of 37,000 m^3/s is unrealistically high considering the maximum mean monthly recorded discharge is 7,230 m^3/s[1] (July 1921), and the maximum mean monthly discharge for all recorded years is 6,234.7 m^3/s (June). This suggests that a factor in addition to discharge played a major role in the flood of 1935, and this factor was undoubtedly a large ice jam in the distributaries of the delta. A local fisherman, John Beaulieu (Pers. Comm., 1978), recalls the ice jamming in the

[1]Slave River discharge data were provided by Water Survey of Canada for 1920, 1921, 1930, 1931 and 1953 to 1977 inclusive.

delta that year. The noise of the grinding ice masses could be heard in Fort Resolution, 14 km from the apex of the delta.

The mid delta (definition given in Section 4.4.2) has levees reaching a maximum of 1.75 m above the mean August 1977 river levels. According to local trappers, these portions of the delta experience flooding every 5 to 7 years (A. Beaulieu and A. Delorme, Pers. Comm., 1977). Records maintained by the Water Survey of Canada (1977) for Great Slave Lake and Slave River suggest that flooding of this portion of the delta occurs less frequently than that and flood levels calculated previously confirm this (Figures 4.6 and 4.7). However, ice damming in the discharging channels may promote flooding of the mid delta at the intervals reported. According to local trappers (G. Lafferty and J. Mandeville, Pers. Comm., 1977) the most recent flood in this portion of the delta was during the early spring of 1974. Using the linear equations described earlier, the flood level described in Figure 4.6 for 1974 is the highest recorded. Coupled with this high flood level, the Slave discharge peaked in early May while air temperatures recorded in Fort Resolution were below freezing[1]. According to Shulyakovskii (1963), these conditions would promote ice damming. Burdykina (1970) reports that ideally ice damming occurs when the river ice upstream of the damming site is broken by the dynamic action of the flood wave while the ice downstream holds firmly in place, creating a

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[1]Although the mean monthly temperature for May 1974 was 5.5°C the first half of the month averaged -2.0°C (Environment Canada, 1975).

suitable location for ice jams. Shulyakovskii (1963) states that two major factors influencing ice jamming in a river channel are a negative air temperature and a rapid rate of water rise in the channel. The great increase in discharge over a 5 day period in 1974 (2,888 m^3/s on 1 May to 11,158 m^3/s on 5 May), coupled with negative air temperatures were principally responsible for promoting ice damming and subsequent flooding of the mid delta zone by the sediment rich spring flood.

The relatively poor bryophyte layer in the mid delta zone lends credence to the occurrence of flooding every few years. Gill (1978) also reports that areas in the Mackenzie Delta, which experience sediment rich floods also support very poor bryophyte communities.

Ice conditions on Great Slave Lake along the outer delta may also encourage flooding. During certain years, ice damming occurs at the mouths of the distributaries (J. Beaulieu, Pers. Comm., 1978) because the lake ice is still holding firm when the spring surge of flood water has disrupted the channel ice in the delta. Once the ice accumulates at the mouths of the channels and forms an ice dam, diversion of the spring flood waters (and accompanying sediment) occurs and portions of the delta are flooded - the areal extent depending upon the location and duration of the ice jam or jams and the amount of discharge.

Shulyakovskii (1963) reports that the depth of snow cover on the ice is important in predicting the duration of an ice jam and the maximum stage caused by the ice damming. Snowfall plays a significant role in the timing of ice breakup as it contributes to a greater propor-

tion of white ice to black ice[1]. Since white ice has a higher albedo than black ice (Adams, 1976), the amount of solar radiation required to melt it is substantially greater. In years of greater snowfall, we may expect the probability of ice jamming to increase, especially if the air temperature is below freezing and the spring flood surge occurs early in May over a short period of time. It is of interest that during the winter of 1974, prior to the spring flood, Fort Resolution received a record snowfall of 264.7 cm compared with a 29 year average (1941-1970) of 154.0 cm.

Conversely, years of relatively low snowfall could also increase the probability of ice jamming because the absence of an insulative snow cover encourages heat loss and promotes a thick ice sheet. Henoch (1960) reports that a thick cover of ice on the Peel River contributes to flooding, whereas a substantial accumulation of snow limits ice thickness and reduces flooding. Therefore, ice conditions resulting from either of the two extremes of ice formation tend to promote the probability of ice damming.

Walker (1969) observed the initial melt period on the Colville delta of Alaska, as the water originating from snowmelt on the delta collected in the channels and along the distal portions of the delta. Melt water in the channels above the channel ice become clouded with sediment locally eroded from the levees. Walker (1969) claims this

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[1]Black ice is formed from lake or river water and white ice is formed when lake, river or rain water mixes with a snowcover on top of the ice. Black ice is transluscent as impurities are exsolved during the freezing process (Adams, 1976) while white ice is opaque.

aids in breaking up the channel ice as the sediment in the water on the channels absorbs radient energy from the sun and consequently aids in melting the channel ice.

4.2 Sedimentation

Soil profiles in the mid delta zone indicate a major deposit of sediment which is attributed to the 1935 flood (Figure 4.8). The thickness of this layer varies from site to site, depending partially on distance from an active distributary, the amount of disturbance by rooting systems, illuviation of suprajacent organic matter into the sediment deposit, and microbial action in the soil. Evidence of this flood is most difficult to detect in the soil profiles dug in the *Picea* assemblages near the delta apex. Immediately below the bryophyte layer is a layer of sediment which is substantially lighter in colour than the underlying soil, this is assumed to be the deposition of the 1935 flood (Figure 4.9). The sediment from this large flood overlies a 10-12 cm layer of decomposing mosses, evidence of a long lasting previous flood-free period in the apex zone.

In portions of the mid delta zone, a more recent layer of sediment was frequently observed in the soil pits just below the litter layer. This was attributed to the 1974 flood. Figure 4.8 illustrates several soil profiles in different areas of the delta, demonstrating the approximate extent of this 1974 flood. In Figure 4.8, mor is defined as organic material not fully decomposed; mull is organic material fully decomposed.

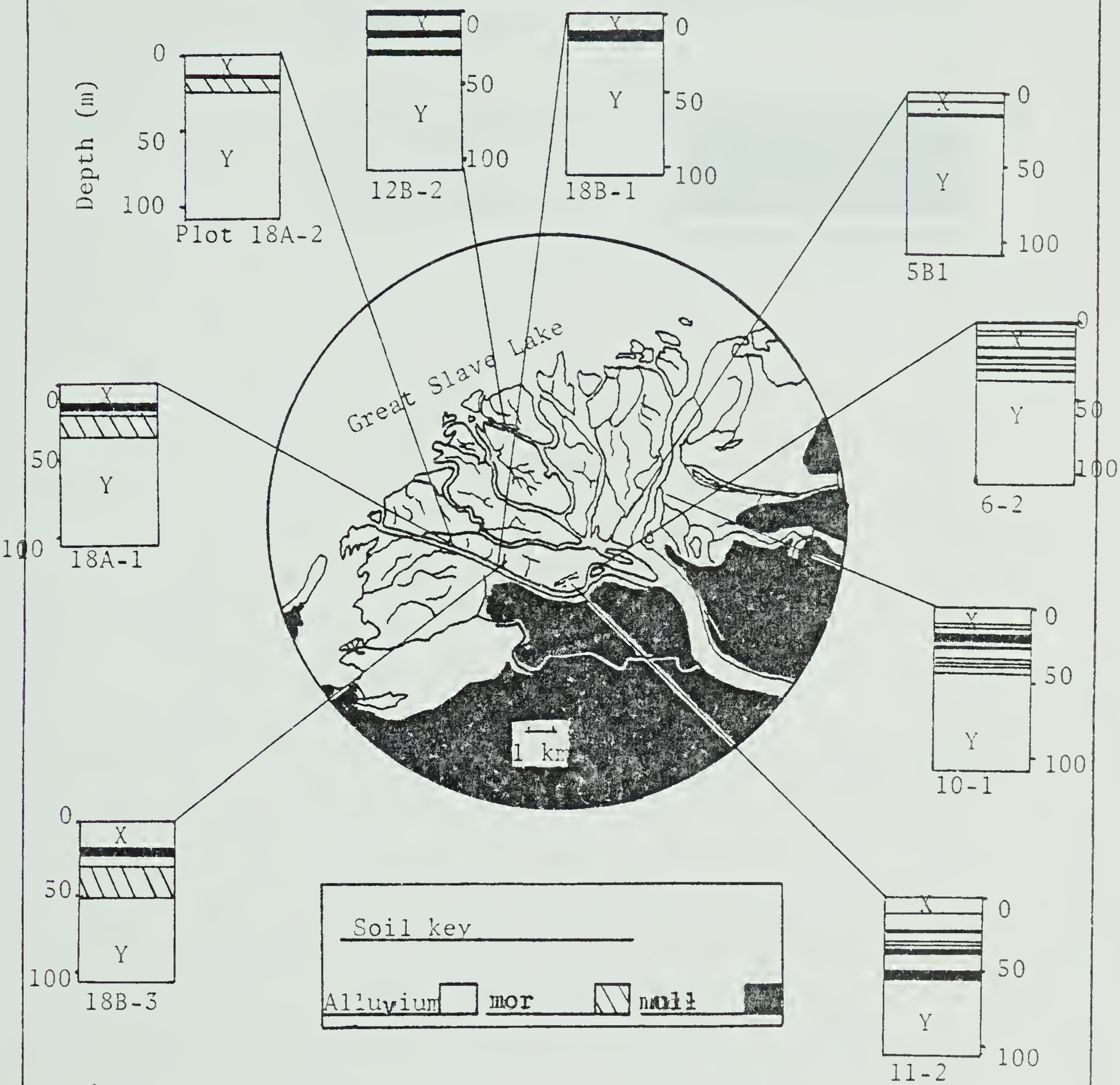

Figure 4.8 : Approximate extent of 1974 flood

The sediment deposit resulting from the 1935 and 1974 floods is indicated in the soil profiles.

1974 X 1935 Y

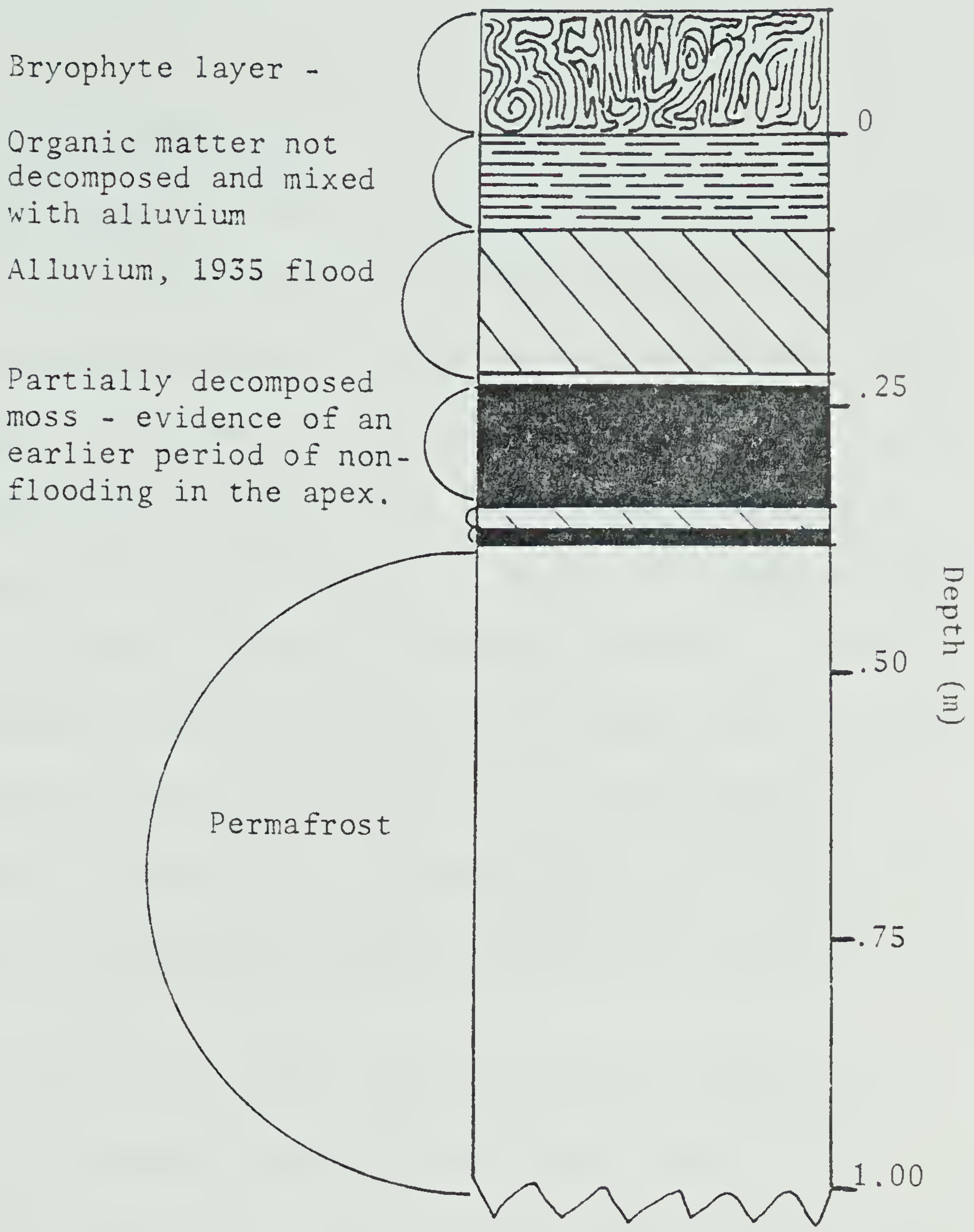

Figure 4.9 : Soil profile, *Picea* assemblage along Transect 4

4.2.1 Suspended sediment load

Yearly suspended sediment records kept for the Slave River (Water Survey of Canada, 1977) include the months of May - October, although May is frequently omitted, because of ice conditions on the river. Occasionally, other monthly readings have been omitted as well. Nevertheless, monthly means for each year (1971-76 inclusive) have been plotted (Figure 4.10). Unfortunately, records were not available for the 1977 study season. The graph in general follows the obvious: an increase in sediment concentration during the spring thaw, peaking when the snow in the western cordillera melts in June followed by a decrease in the fall. Figure 4.11 illustrates the close relationship between discharge and suspended sediment concentration in the Slave River for 1976[1].

Water Survey of Canada (1977) records the particle size distribution of the suspended sediment in the Slave River at Fort Fitzgerald for 1971 through 1974. Unfortunately, data for only four years were available and the dates of sampling vary. It is interesting to note, however, that on average 72% of the suspended sediment sampled is composed of silt and clay and of this figure 26% is clay. Comparison of the grain sizes of suspended sediment in the Slave River with the grain size analyses performed on 120 soil samples taken from various locations on the delta indicates that very little clay, in the order of 1%[2], being deposited during the flood periods. Analysis of

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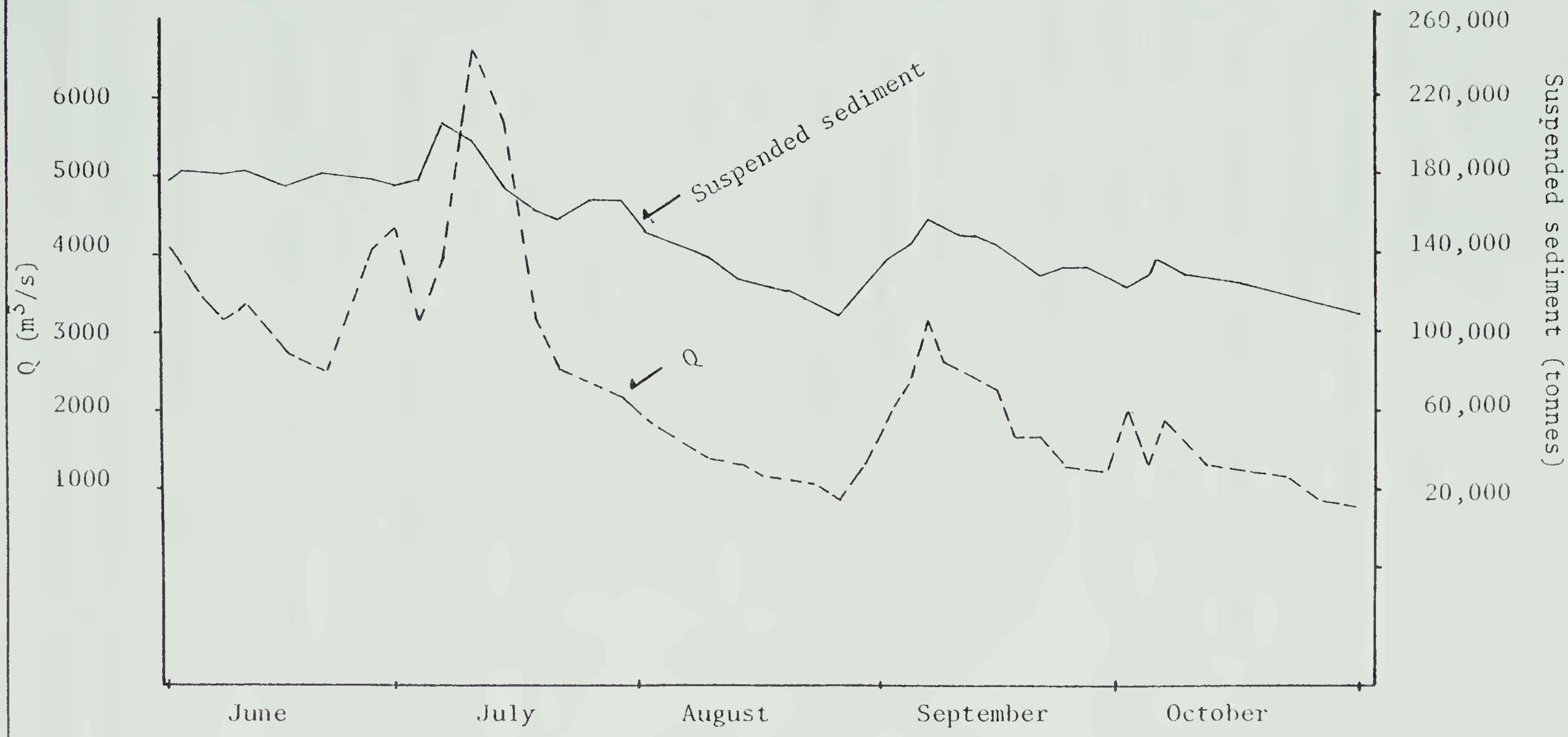
[1] Suspended sediment data were not provided for 1977.

[2] Three samples were analyzed for clay by the x-ray defraction technique (McKeague, 1976); it was found they contained 0.8%, 1.2% and 1.0% clay.

Figure 4.10: Mean and range of suspended sediment load, Slave River at Fort Fitzgerald 1971-1976 inclusive (monthly means).

Figure 4.11 : Comparison of 1976 daily discharge (Q) and suspended sediment for Slave River at Fort Fitzgerald.



some duplicate samples by the Alberta Soils and Feed Testing Laboratory confirmed the low percentages of clay found in the sediment deposited on the delta. The maximum clay content measured was 3% in one sample.

The low percentage of clay in the soil can be partly explained by the great deal of time it takes for clay to settle out of the water column, even under stable laboratory conditions. During a flood the water is anything but stable as the eddies created in the diverted streams are quite strong.

A useful comparison can be made between the particle size of suspended sediment carried by the 1974 flood and the sediment deposited on the Slave Delta during that period (Figure 4.8). Figure 4.12 indicates that little of the available clay fraction in the flood waters was deposited. By converting the percentages found in the sand, silt and clay fractions of the discharge to tonnes of suspended sediment, 72,574 tonnes of sand, 120,520 tonnes of silt and 68,906 tonnes of clay were available for deposition downstream, a sand-silt-clay ratio of 1.1:1.7:1. Analysis of the 1974 flood deposits on the delta indicates that a ratio of 25:51:1 is present in that sediment (Table 4.2). The difference in the two ratios is largely due to the fact that more bedload than suspended sediment is being deposited during these floods. Unfortunately, there are no bedload data available for the Slave River.

Although attempts were made to measure the amount of sediment deposited during the 1977 flood in the interlevee depressions of the outer delta (Section 4.4.1) the thick rhizomes of *Equisetum fluviatile* prevented accurate measurement. However, this work enabled

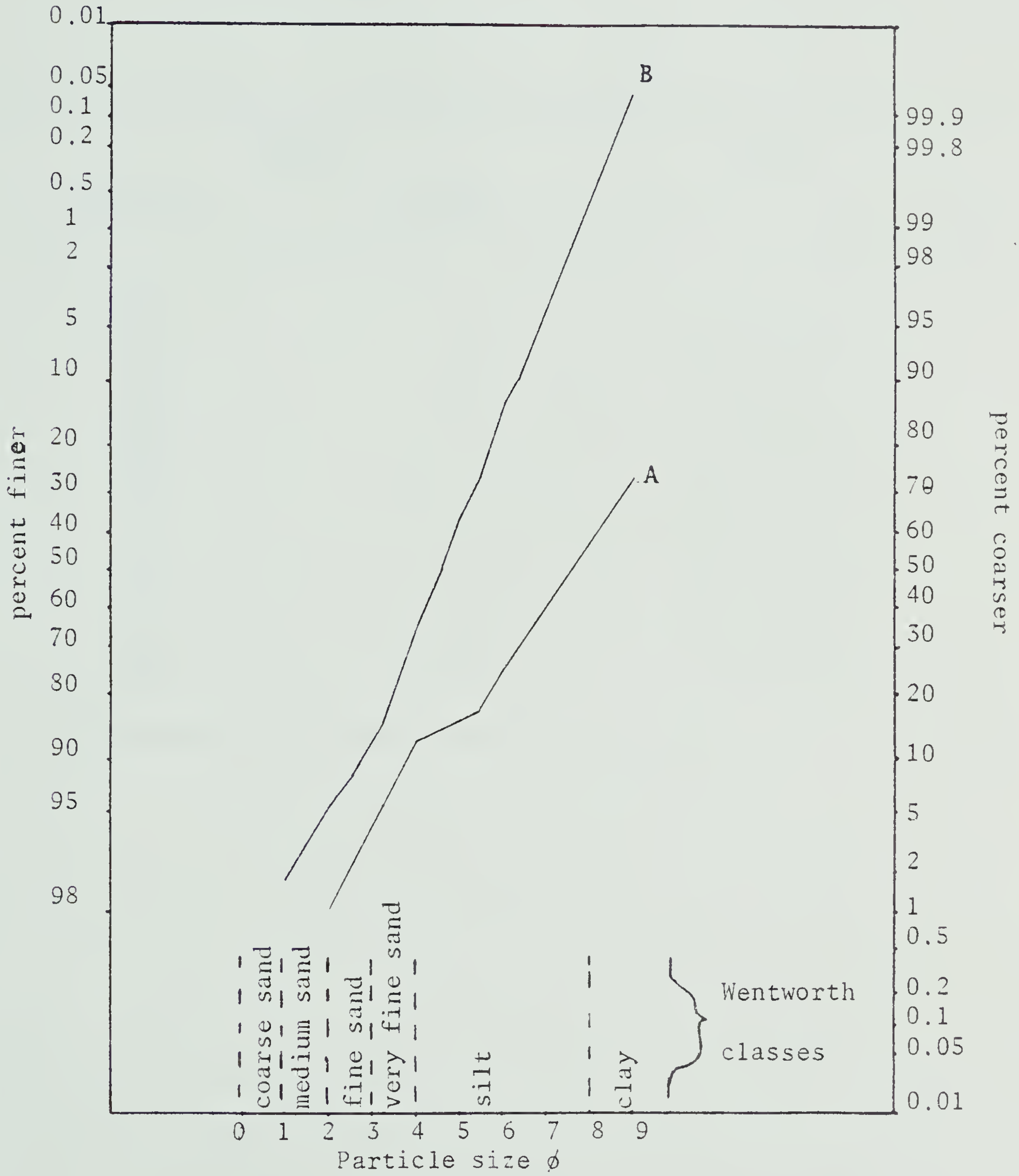


Figure 4.12 : Comparison of suspended sediment particle size in the Slave River, spring 1974 (A), and sediment deposited on the Slave River Delta, spring 1974 (B).

Table 4.2: Sand-silt-clay ratios of the 1974 flood deposit from selected sites.

Sample		Ratio
Transect	Plot	
18A	B	23.8:52.0:1
18A	A	34.2:48.2:1
18B	A	70.0:129.0:1
18B	C	27.5:55.7:1
5B	1	29.0:70.0:1
6	2	8.3:40.0:1
10	1	28.7:37.0:1
11	1	27.3:62.6:1
18C	A	17.0:32.0:1

a rough estimate of 0.10-0.15 m for the thickness of sediment deposited during this flood.

A more accurate indication of annual sedimentation rates was found on Rabbit Island in Steamboat Channel. This island was not included on a map of the delta published by Brown in 1950 (Figure 4.14). Figure 4.17 illustrates the layered pattern of sediment and organic matter in this typical Cumulic Regosol. The number of distinguishable layers and the low elevation of the site (Figure 4.18 - soil pit B) indicate that spring flooding is experienced frequently. The dense growth of *Salix interior* at this site annually provides a leaf litter which is buried the following spring and the cycle starts anew. Correlation of previous flood levels with the thickness of the deposits produces some useful information on the previous flooding and sedimentation history of this island. The locations of the soil pits sampled along transect 6 are shown in Figure 4.18. The level of the 1977 flood is also shown. The approximate developing profile of Rabbit Island since 1957 is shown in Figure 4.19. Although specific dates cannot be given to the sediment layers below the 1974 deposit, the age of the shrub layer gives some indication of previous geomorphological history and a range of years can be assigned to these sediment deposits. The maximum age of *Alnus tenuifolia* at this site (Figure 4.18) is 15 years while *Salix arbusculoides* ranges in age from 14 to 18 years. *Salix interior*, a species common along the lower lying perimeter of this island is absent in the Alnus assemblage (Figure 4.18). Assuming this portion of the island formed the 1957 shoreline

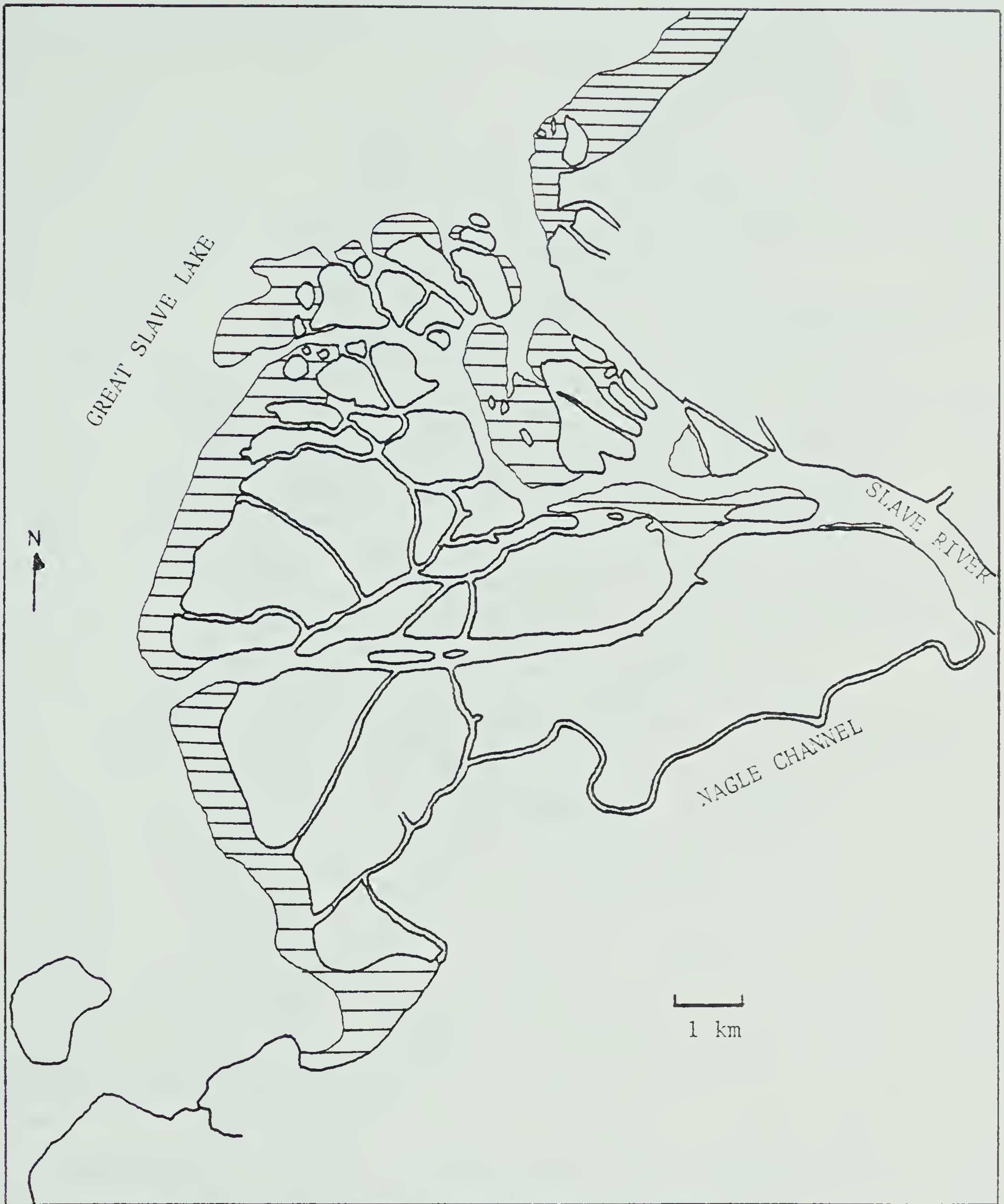


Figure 4.13: Slave River Delta 1922 (Blanchet, 1922).
The hashed lines represent submergent bar development.
Nagle Channel remains in virtually the same position
in 1977.

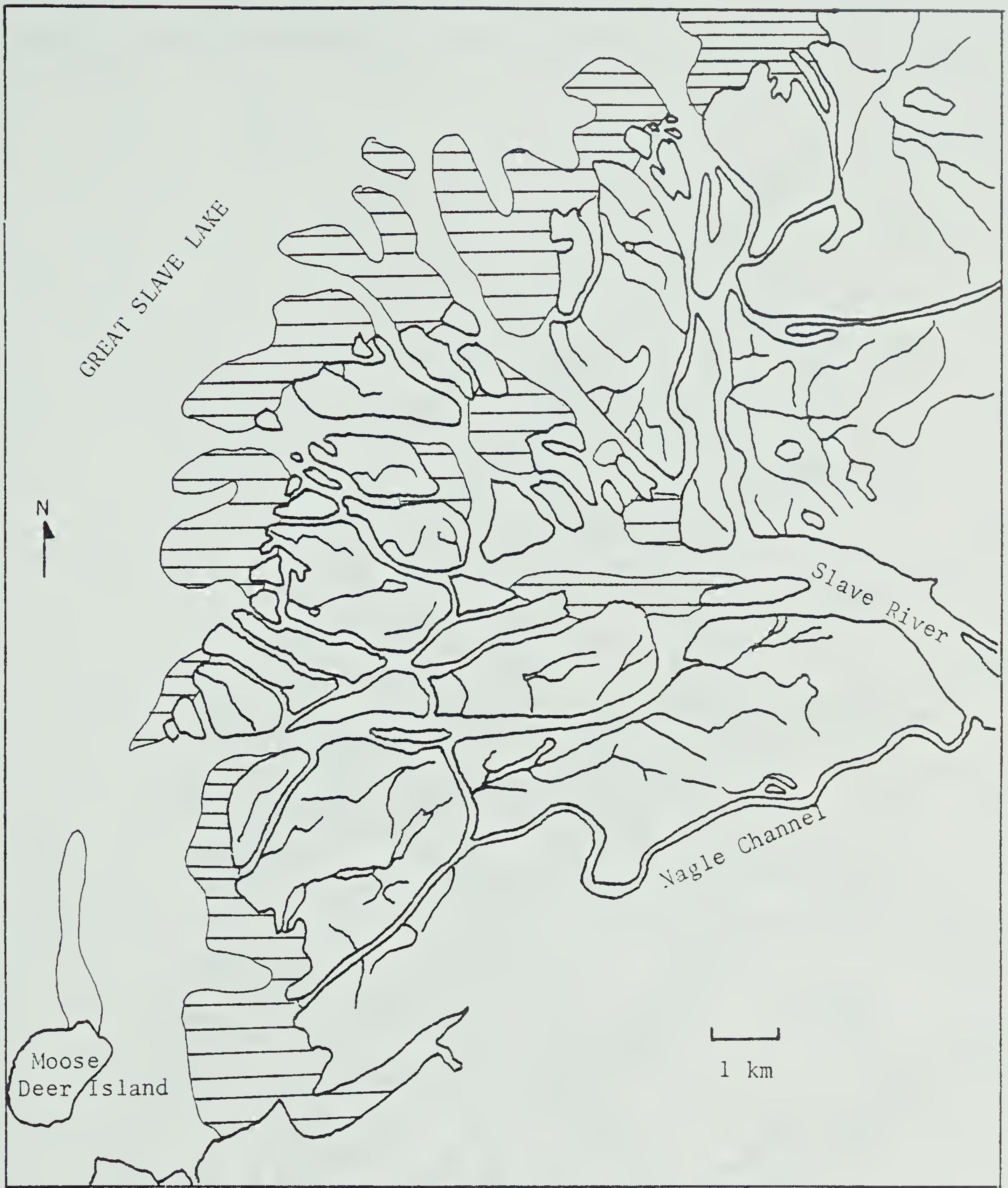


Figure 4.14 Slave River Delta 1950 (Brown, 1950).
The hashed lines represent submergent bar development.

Figure 4.15: Slave River Delta 1971 (Day 1972)

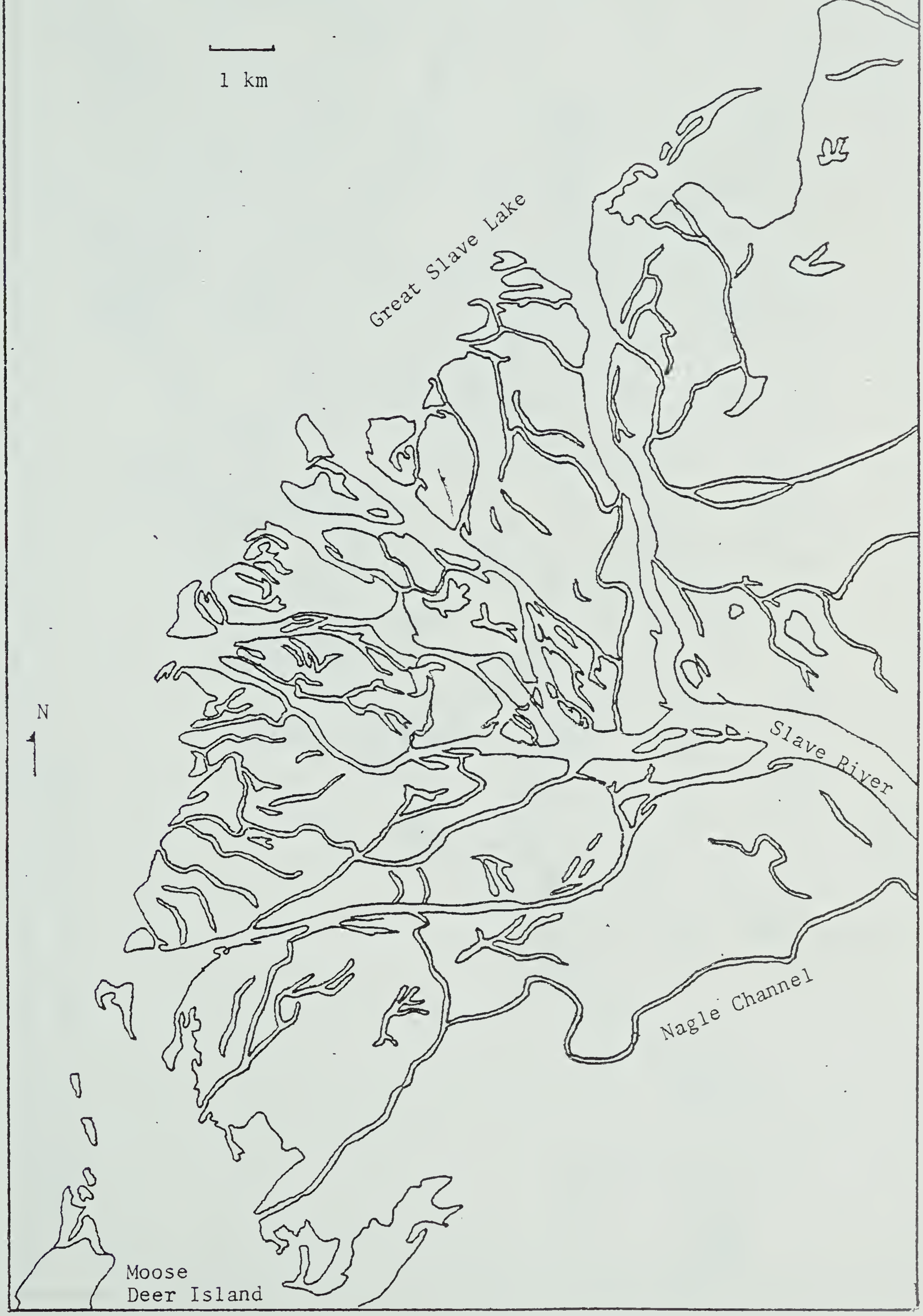


Figure 4.16: Slave River Delta, 1977

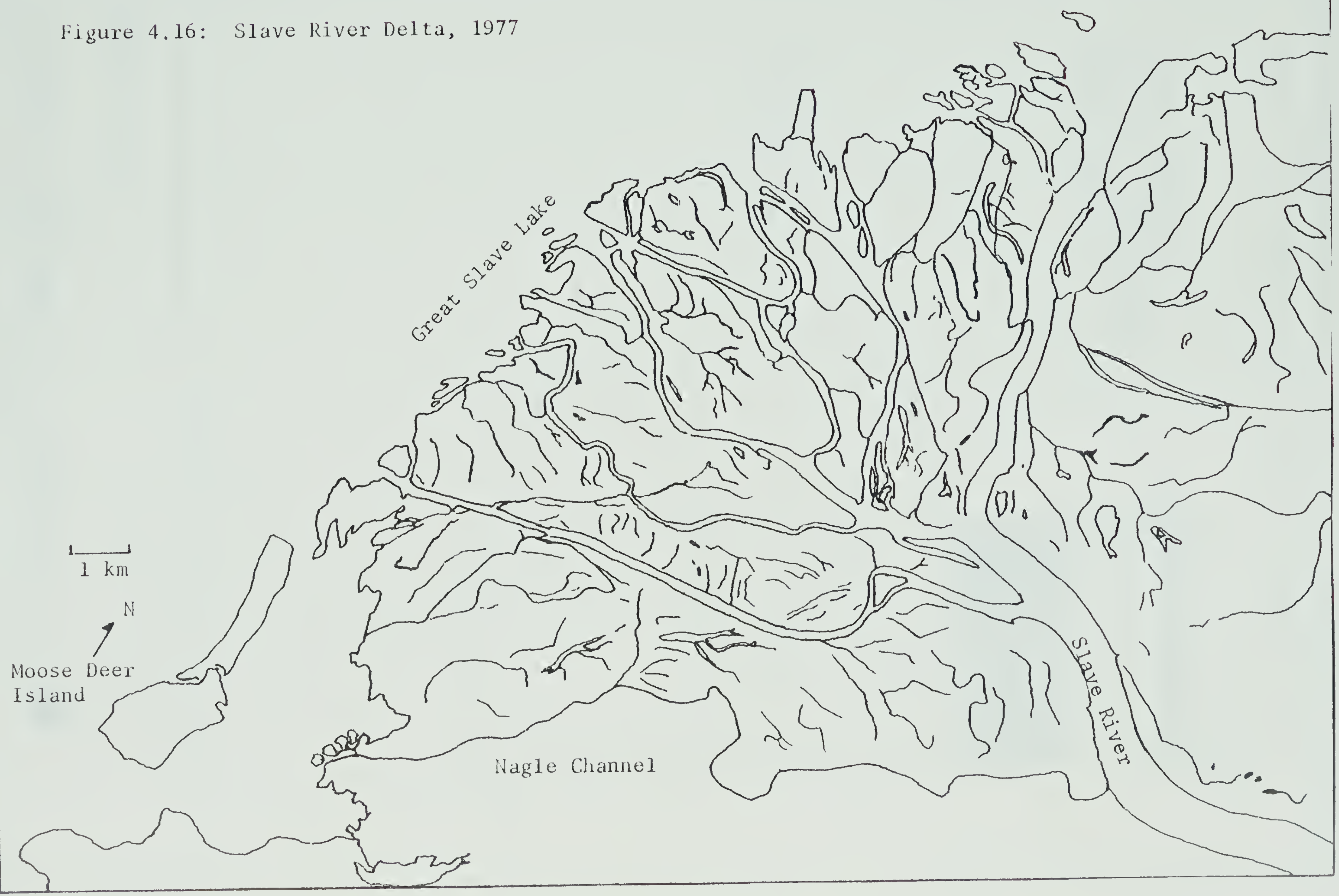
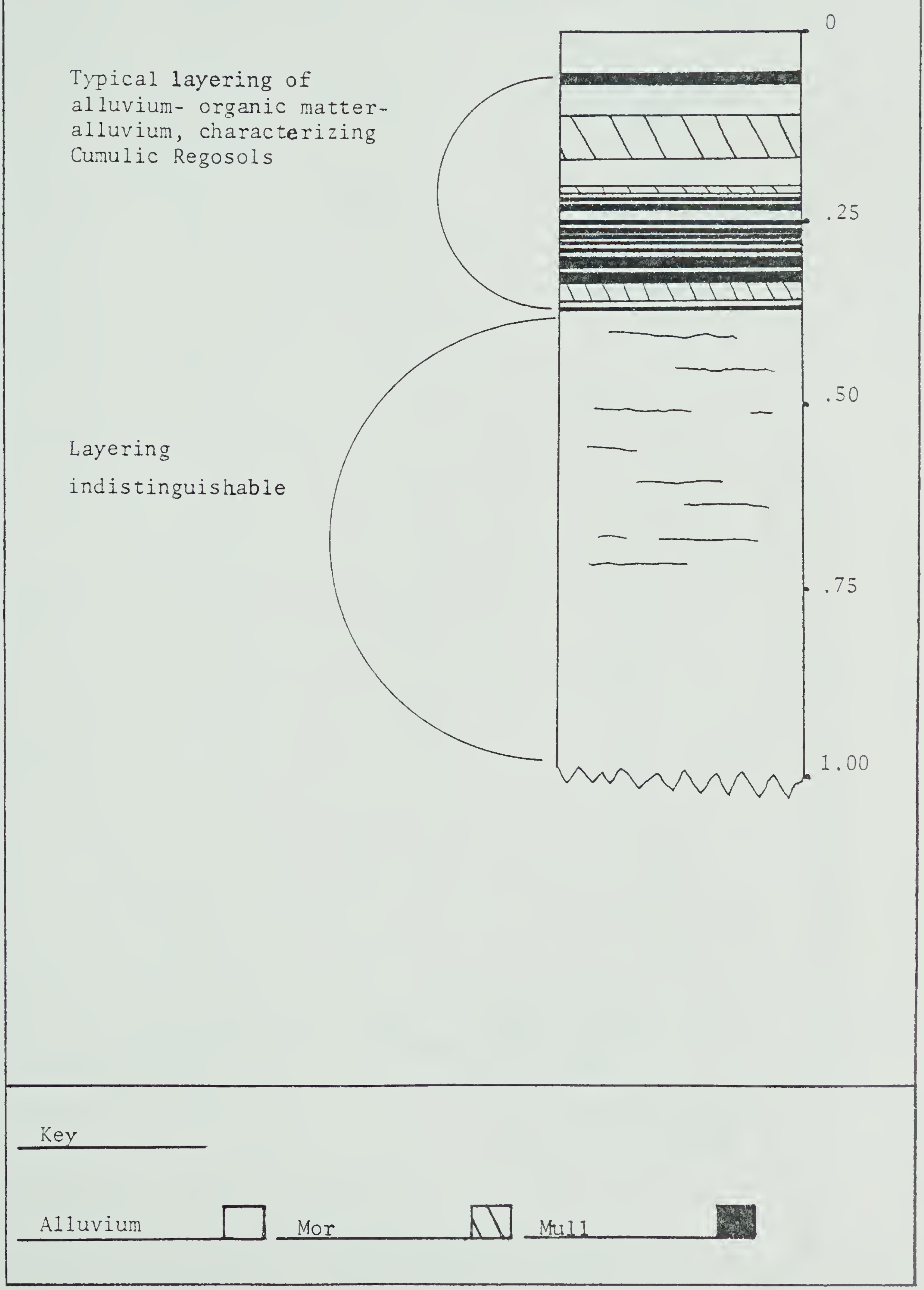


Figure 4.17 : Cumulic Regosol sampled on transect 6 plot 1



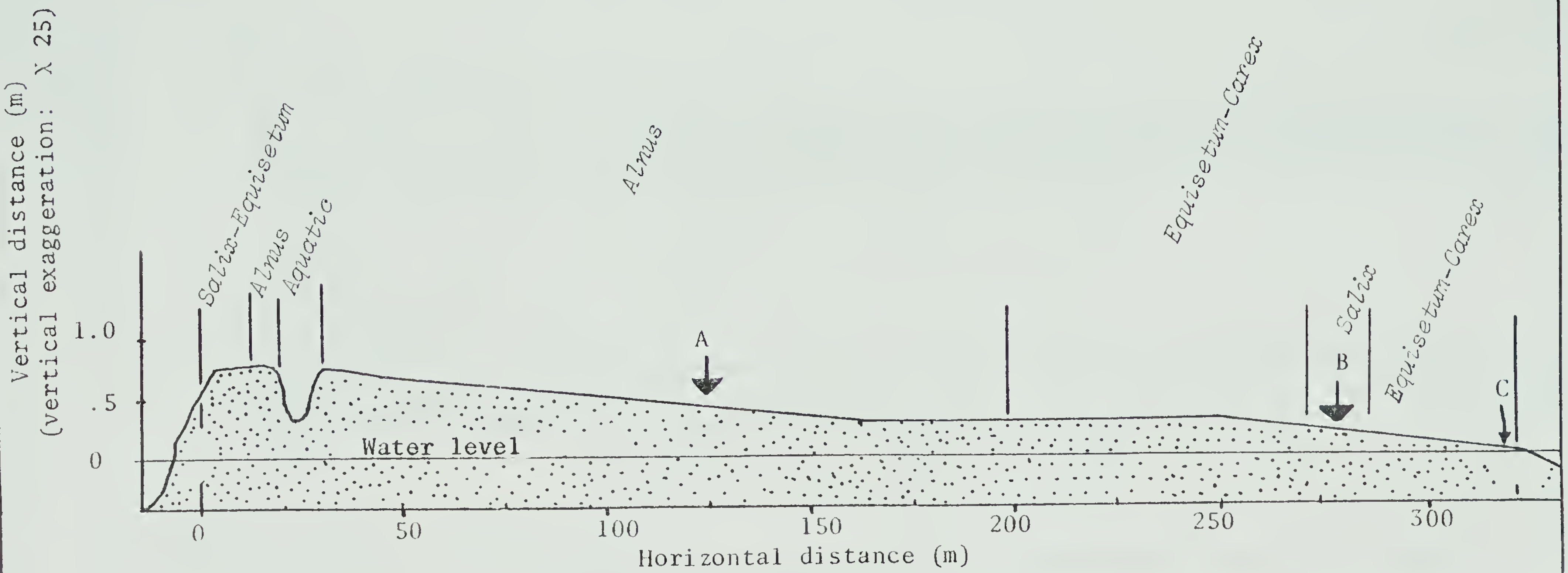
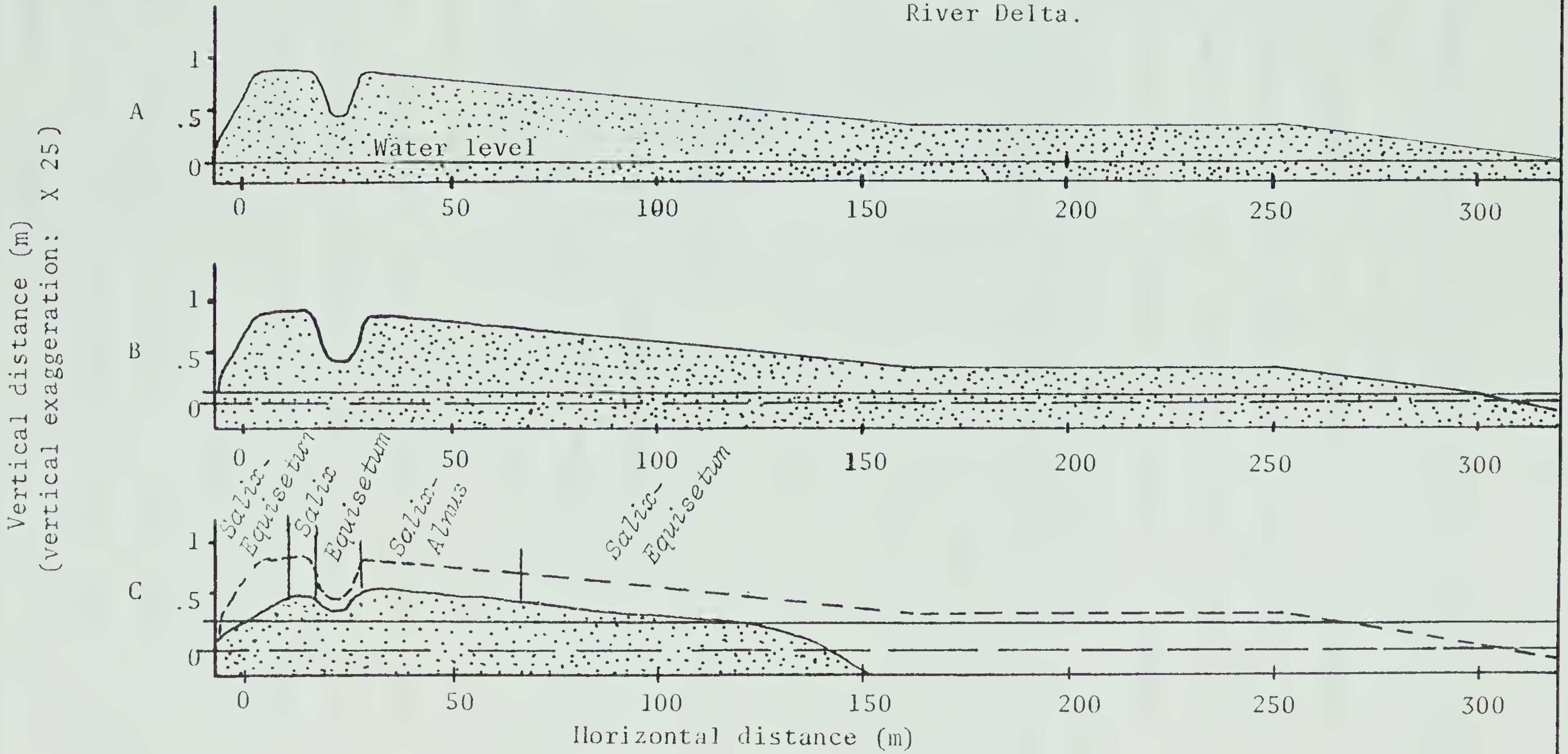


Figure 4.18: Transect 6, plant assemblages (sampled 28 June 1977). Soil pit locations indicated (A and B) as well as the maximum level of the 1977 flood (C).

Figure 4.19: Probable geomorphological development of Rabbit Island, Steamboat Channel, Slave River Delta.



A. The 1977 profile of Rabbit Island.
B. The 1973 profile. The solid horizontal line indicates the low summer water level of 1973. The dashed line is the 1977 low summer water level.
C. The 1957 profile. The solid horizontal line indicates the low summer water level of 1957. The dashed line as in B. The plant assemblages most likely inhabiting the island are shown. The dotted line represents the amount of sediment deposited between 1957 and 1973.

of Steamboat Channel, the distinguishable layers of sediment below the 1974 layer must have been deposited between 1957 and 1973. Referring back to Figures 4.6 and 4.7, the floods of sufficient height to deposit this sediment occurred during 1960, 1962-1965 and 1967. Since the low summer river level of 1957 was 0.20 m above that of August 1977, a baseline for 1957 was used to delineate the emergent extent of the island profile along the transect (Figure 4.19). Development of the remaining portion of the island took place over an 8 year period, 1950-1957. The oldest willow species, found on what appears to be a meander scroll depression (Figure 4.18), began growing approximately in 1952.

4.3 Landforms

4.3.1 Introduction

The factor primarily responsible for the genesis of land-forms on the Slave Delta is the seasonal fluctuation of the Slave River discharge and its accompanying sediment load. While form and structural change within the delta are governed primarily by river regime, the arcuate shape of the delta's leading edge is produced by the prevailing northwesterly winds and accompanying wave action of Great Slave Lake during the ice free months. Another factor playing an important role in the delta's shape and growth is the location of master channels that contribute the major amounts of sediment for distal growth. The lake current (Plates 1 and 2) created by the discharge of Slave River into Great Slave Lake creates a counter clockwise vortex within the western arm of the lake and is a factor in

100 m

Plate 1: Sediment discharge from Slave River Delta. The thermal imagery flown 7 September 1977 illustrates the flow of the discharging sediment. The discharge from Resdelta Channel (a) creates a current sufficiently strong to draw the discharging water from the other channels to the south along the outer perimeter of the delta.

Courtesy, Canadian Wildlife Service.

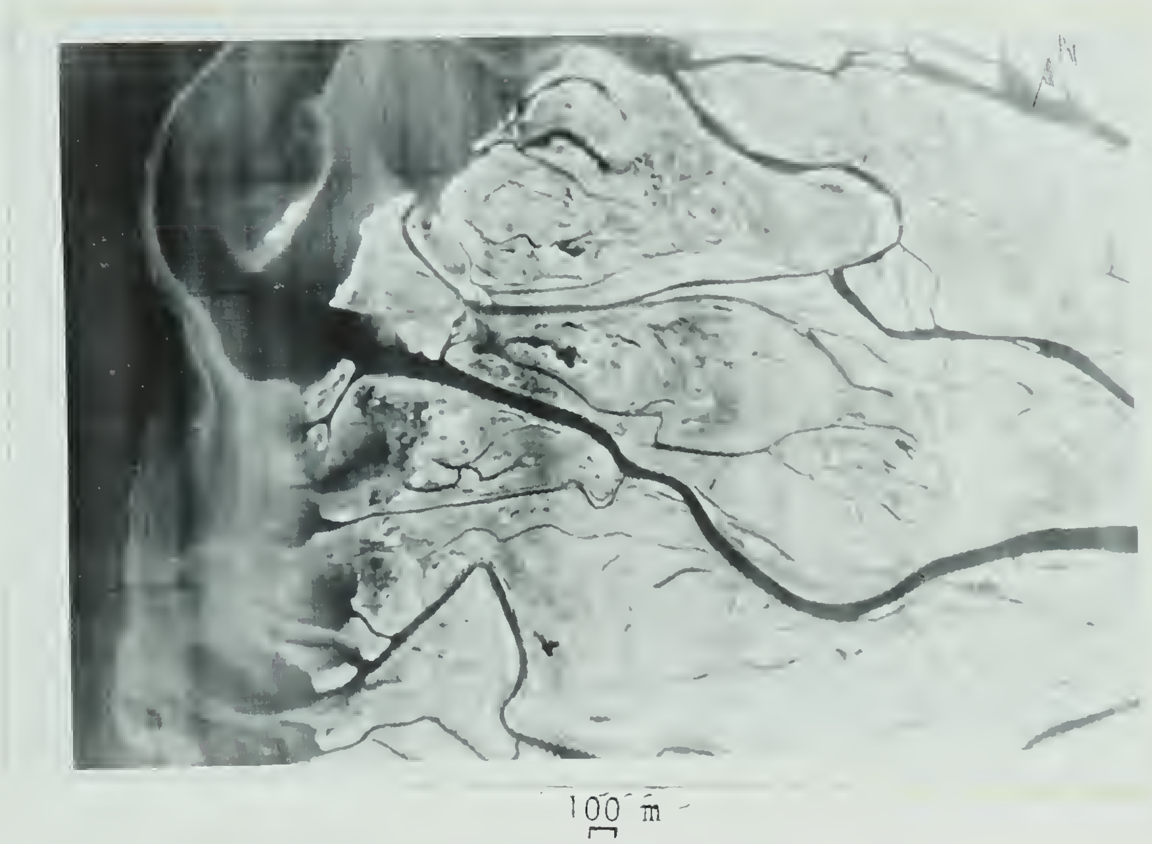


Plate 2: Sediment discharge from Slave River Delta. The thermal infrared imagery flown 7 September 1977 illustrates the flow from the discharging channels.

Courtesy, Canadian Wildlife Service.

the geomorphological evolution of the outer delta (Section 4.4.1).

As the delta matures from initial cleavage bar development, vegetation plays a larger role in stabilizing the landforms against erosion and retaining sediment deposited during flood-stage. In the outer delta, however, physical factors, such as the river's discharge and wave erosion, play a greater role in shaping the landforms than in the older portions.

4.3.2 Cut-bank levees

The most prominent landforms on the delta are cut-bank levees. As defined by Gill (1972:124), they form along concave distributary banks where lateral destruction of the floodplain by fluvial erosion is intermittently accompanied by alluviation along the crest of the concave bank near the channel edge. Cut-bank levees range in height (above the August 1977 mean river level) from approximately 0.25 m for the younger islands of the delta, to approximately 3.0 m in the apex zone. Since these sites are the highest in elevation on the delta, they are quite frequently occupied by *Populus balsamifera* assemblages, as the requirements of this tree are met in the mesic environment provided by the levee (Plate 3). Cut-bank levees less than 0.50 m above water level are usually inhabited by Alnus-Salix assemblages (Plate 4).

In the Slave Delta, permafrost does not play as large a role in the recession of cut-bank levees as it does in more northerly floodplains (Gill, 1972b),because its presence is largely confined to Picea stands which are, for the most part, segregated from the active

Plate 3: A cut-bank levee upon which the base camp for the 1977 field season was located. Most of the south-facing cut-bank levees throughout the delta are free of snow at this time of year (27 April 1978).

Plate 4: An *Alnus-Salix* assemblage inhabiting a cut-bank levee.

distributaries by levees occupied by *Populus* assemblages. Usually these levees are composed of dry sandy or silty loam which effectively deters formation of permafrost. The large pore spaces of this sediment encourages rapid infiltration of moisture. Soil moisture content in the levees averages 6% near the surface and 15% at depths of 1 m. Soil temperatures are therefore warmer in these comparatively dry soils.

The mesic environment of these landforms is attributed by Axelsson (1967) and Gill (1971) to their mode of formation and to the comparatively large alluvial fractions deposited on them during flood-stage. The levees of the Laitaure Delta (Axelsson, 1967), Kvikkjokk Delta (Dahlskog, *et al.*, 1972) and the Mackenzie Delta (Gill, 1971) all contain coarser material than the interlevee depressions or the levee backslopes. Because of the larger particle sizes and the mode of sediment deposition, cut-bank levees are built up more rapidly than other landforms, and are therefore more susceptible to the drying effects of interior soil drainage and wind. In the Slave Delta, exposure to wind and intense solar radiation penetrating the leafless vegetation make these elevated cut-bank levees the first landforms to become exposed during early spring snowmelt (Plate 3). Because these levees heat up earlier they usually have a longer growing season than other delta landforms. Gill (1971) found that the elevated levees in the Mackenzie Delta also experience a longer growing season.

4.3.2.1 Erosion

Strandline or wave erosion plays a prominent role

Figure 4.20 : Location of place names listed on Table 4.3 .

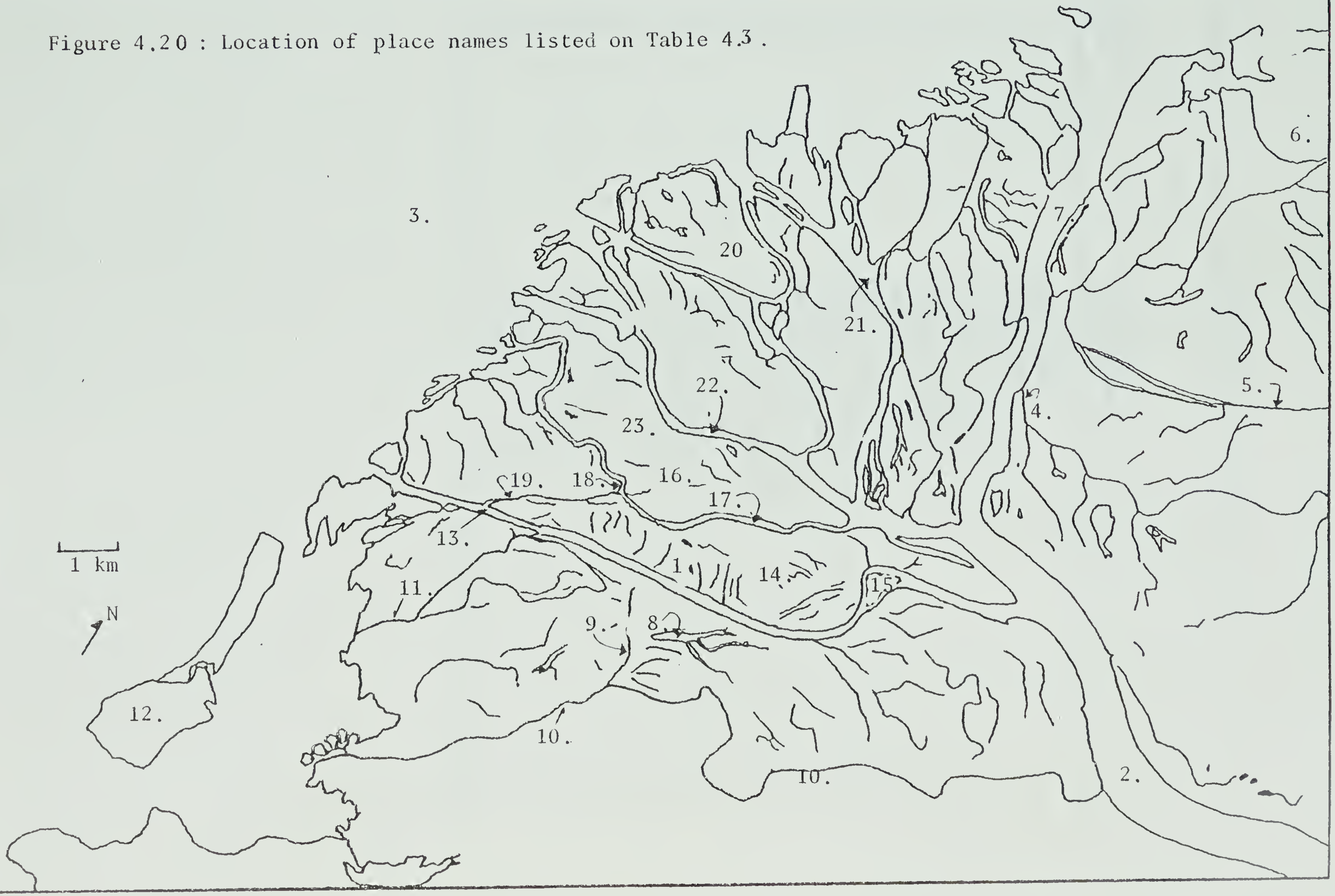


Table 4.3: Local place names shown on Figure 4.20.

Number	Place Name
1	Base Camp
2	Slave River
3	Great Slave Lake
4	Little Fishery
5	Little Jean River
6	Jackfish Bay
7	Resdelta Channel
8	Willow Lake
9	Sawmill Channel
10	Nagle Channel
11	Whiteman's Channel
12	Moose Deer Island
13	Steamboat Channel
14	Mouse Island
15	Rabbit Island
16	Checker Island
17	Checker Channel
18	Four Ways
19	Four Ways Channel
20	Gabes Island
21	Jesses Channel
22	Middle Channel
23	'Unnamed' Channel

in the erosion of cut-bank levees. Strandline erosion is defined as the fluvial action on a cut-bank - including wave action and the discharge of the river. Strandline erosion is of greatest consequence when the wind direction is from the northeast causing the wind to run parallel to, but against the flow of several of the delta's distributaries. A change in wind direction is often accompanied by a low pressure system and precipitation, which serves to increase the discharge of the river. Although such change in wind direction is infrequent, the erosional effect upon cut-banks receiving wave action and increased discharge is measureable. The most active area of cut-bank erosion in the delta is the left bank of the main channel of the Slave River, just downstream from the beginning of Nagle Channel. During the 1977 field season the shoreline along this channel retreated approximately 1.5 m along a 500 m section. Most of this erosion occurred during northeast storms; Plate 5 illustrates the effect of one such storm which lasted for two days (9 and 10 June, 1977).

Plate 6 shows the erosive effect of this same storm on a cut-bank levee on Checker Channel (Figure 4.20). Although wind speeds were not measured, whitecaps were observed on Checker Channel for the two day period. Approximately 0.2 m of levee was eroded as the constant wave action removed the supporting sediment at water line resulting in the slumping of sediment into the channel.

Minor erosion occurs along the faces of these levees during the early spring melt period as was observed in late April 1978. Snowmelt runoff erodes small gullies along the face of

Plate 5 : Cut-bank levee erosion along the left bank of the Slave River, just downstream from the apex of the Slave River Delta. The effects of a two day storm (9 and 10 June 1977) is illustrated.

Plate 6 : Erosion of a cut bank levee.
The slumping of a large wedge of this cut-bank near Four Ways occurred during a two day storm (9 and 10 June 1977).

the levees as melt water follows a common route to the lower elevations of the channel ice.

Cut-bank levees along Nagle Channel are bound by dense rooting system of *Populus balsamifera*, *Alnus tenuifolia* and in some instances *Picea glauca*. Shrubs, such as *Cornus stolonifera*, also aid in preventing erosion of these levees. Although the roots of these plants help to secure the levees, erosion does occur, usually because of undercutting at water level by river action. When the levees are undercut in this fashion, wedges of alluvium slump away from the parent body, but remain attached for a time by the profusion of roots. Such slumping is widespread along Nagle Channel, but is not frequently seen along other distributaries. The effectiveness of the rooting systems in retarding these wedges from slumping into the channel was exemplified in one location by a three year old *Cornus stolonifera* which was growing from the interior face of the wedge. Plate 7 illustrates one such wedge.

Erosion in this channel appears to be minimal as there has been virtually no change in the position of the channel since 1922 (compare Figures 4.13 and 4.16). A plausible explanation for this is that the channel may carry little bedload. Axelsson (1967) states that the deltaic pattern is usually changed more rapidly in distributaries that transport large amounts of bedload. Channels transporting mainly suspended sediment undergo little structural change over long periods of time.

4.3.3 Point bars

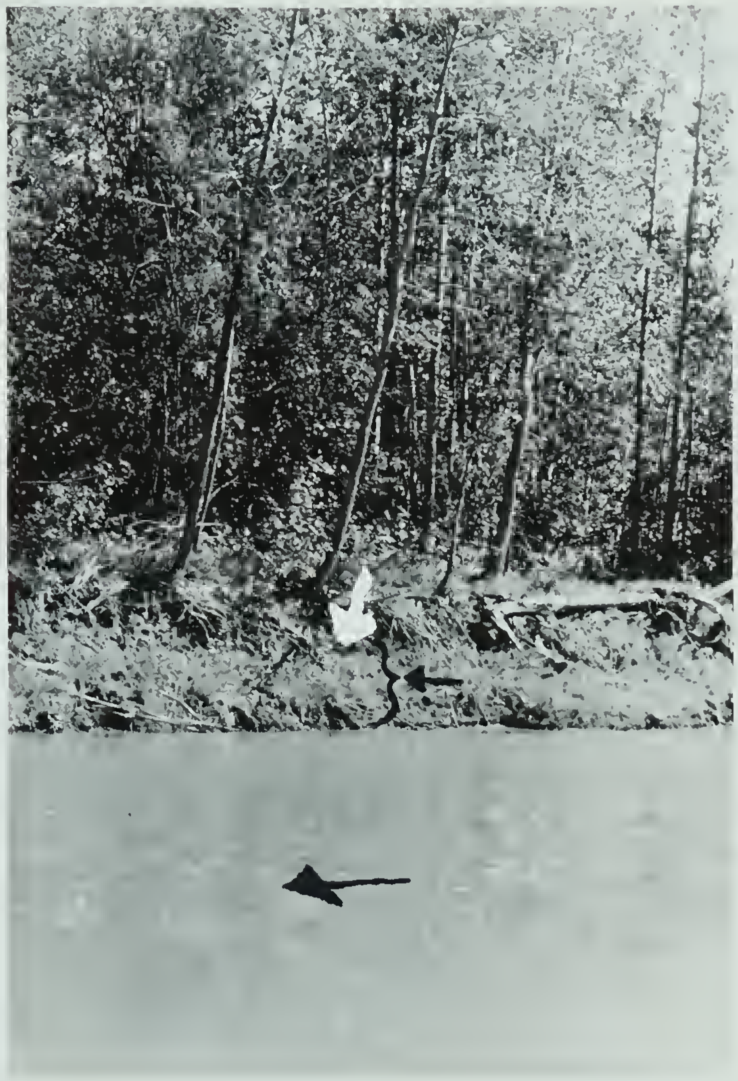


Plate 7 : Slumping of a levee wedge (arrow) during late stages.

4.3.3.1 Development

Sundborg (1956) states that point bar development begins when an arcuate shaped submarine bar composed of bedload begins to develop parallel to the convex bank of a meander curve. He emphasizes the importance of pioneer species of vegetation in aiding the buildup of the bar by trapping sediment.

Point bar formation results largely from deposition of bed load along the convex bank of a channel meander by helicoidal flow (Reineck and Singh, 1975). The "shape and size of point bars vary with the size of the river. In smaller streams point bars are simple depositional features on the convex sides of the meanders dipping gently toward the channel. In large rivers point bars are composed of scroll shaped ridges alternating with depressions" (Reineck and Singh, 1975:231). Because this process depends upon the motion of the river rounding a meander and the subsequent interaction with the centrifugal force of the different densities of the suspended sediment load and the bedload, the point bar formation does not rely solely upon the spring flood for its development (Wolman and Leopold, 1957; Axelsson, 1967). The growth of a point bar is an ongoing process throughout the ice-free year.

Leopold and Wolman (1957:784) state that the prograding point bar "helps concentrate shear against the concave bank" (cut-bank levee) and this promotes lateral migration of the channel. The amount of deposition on the point bar is dependent upon the amount of erosion along the channel concerned, which in turn is a function of

many factors such as the discharge of the river and the amount of sediment being transported, as well as variations in the local climate (Leopold, *et al.*, 1964; Leopold and Langbein, 1966; Nunnally, 1967; Gill, 1972a.

4.3.3.2 Point bar development in the Slave Delta

The development of point bars in the Slave Delta appears to follow the formation by helicoidal flow described in the literature. Most point bar development occurs along the smaller distributaries such as Checker Channel where the meander amplitude is minimal. The point bar, adjacent slip off slope levees (as described by Gill, 1972a) and cross channel cut-bank levees occur in this channel (Plate 8). The cut-bank levees average 0.75 m above the mean August 1977 river levels and are principally vegetated by the *Alnus-Salix* vegetation assemblage. The dense rooting system of this vegetation aids in reducing erosion along the concave levee. Occasionally the littoral zones along these cut-bank levees are inhabited by *Scirpus microcarpus*, *Equisetum fluviatile* and *Equisetum palustre*. This emergent vegetation also acts as a buffer against the erosive force of the river. Because the meanders in this channel are slight, the thalweg is not forced to the concave bank as abruptly as it would be around a tight meander loop. This helps to account for the small amount of erosion along the cut-bank levees, and the prominent growth of emergent vegetation in their littoral zones. The slopes of the point bars on this channel indicate that formation largely occurs during spring high water. Blatt, *et al.* (1972) and Allen (1973)

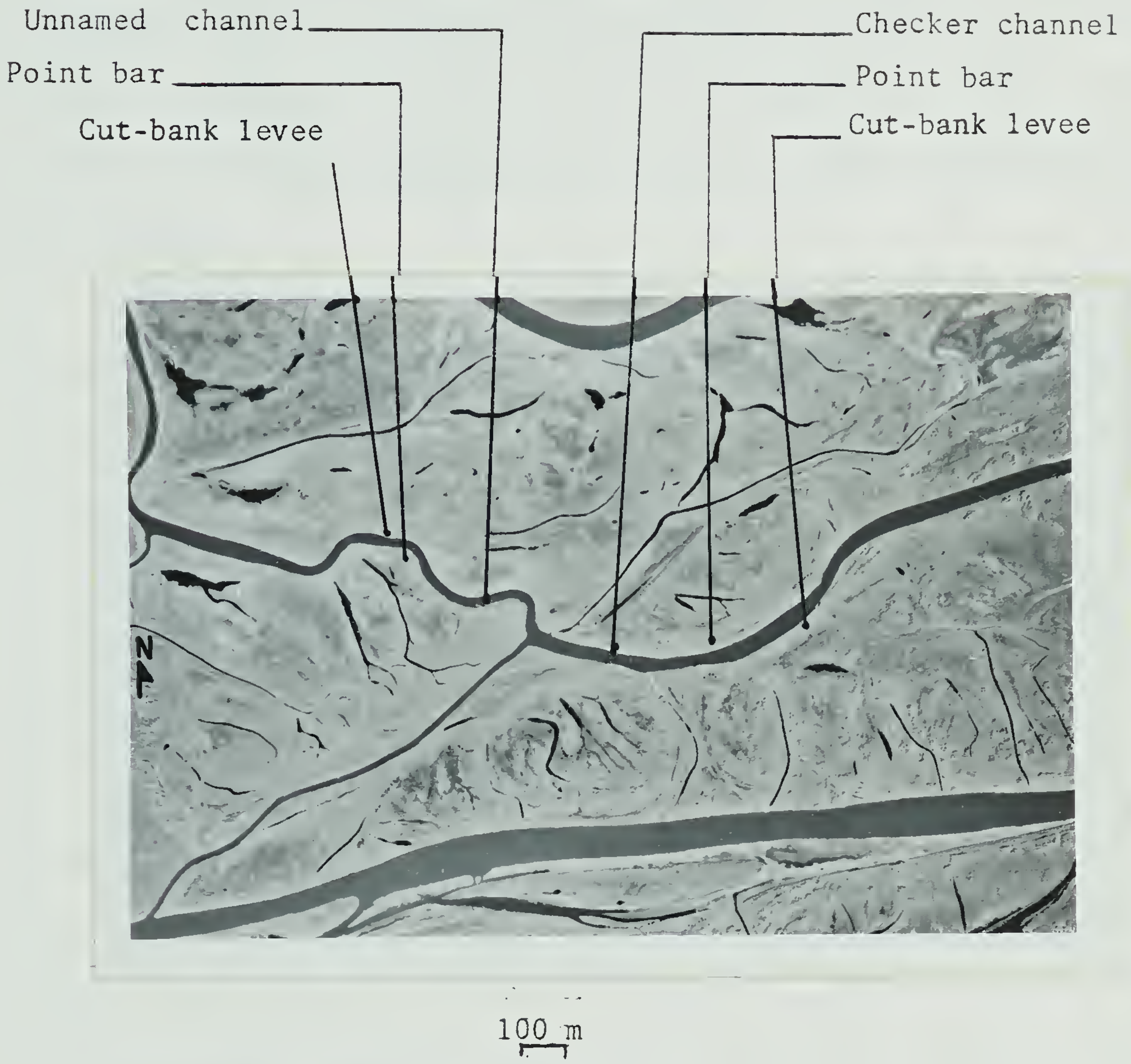


Plate 8 : Panchromatic aerial photograph illustrating point bar - cut-bank levee distribution along Checker Channel and the unnamed channel.

Courtesy, Canadian Wildlife Service.

report that point bar accretion is greatest during the annual flood when the sediment load is great and the river stage is high. The sharp drop along the slope of the point bars in Checker Channel (Figure 4.21) may indicate that helicoidal flow is not very efficient in this channel. The barely perceptible meandering of this channel means that the centrifugal force needed to generate helicoidal flow is not strong.

The unnamed channel leading to Great Slave Lake northeast of Four Ways (Figure 4.20) demonstrates a more typical point bar and cut-bank levee development. The meander loops are much tighter along this channel thus the point bars "prograde" more sharply into the channel than those on Checker Channel (Plate 8). The tighter loops increase the centrifugal force on the sediment layers in the channel and promote more effective helicoidal flow.

Vegetation composition and development is much the same along the point bars and opposing cut-bank levees of the unnamed channel as is found along Checker Channel. The major difference is the absence of littoral emergent vegetation along the levees in the unnamed channel. This is due to the tight meander loops forcing the thalweg against the cut-bank levees, promoting environment for the invasion of emergent vegetation. The only differences observed in point bar vegetation areal extent is that dictated by the amplitude of the meanders which dictates the geometrical shape of the point bars. Where meander amplitude of the distributary is small and meander length is great as in the case of Checker Channel (Figure

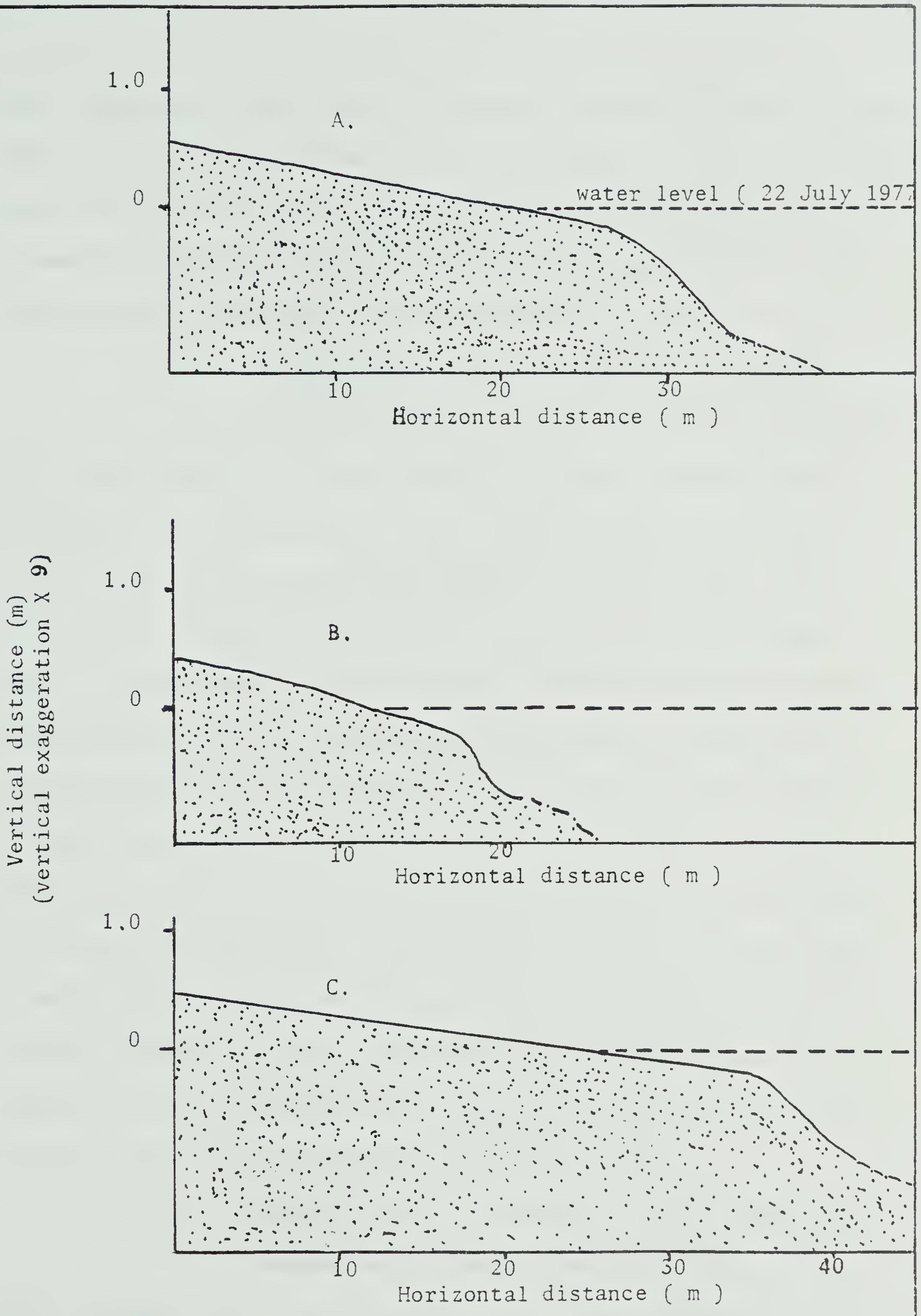


Figure 4.21 : Point bar profiles on Checker Channel (A and B) and the unnamed channel (C).

4.22), boundaries of the point bar vegetation growth will have a large length (distance along the shore) to width (distance from the leading edge of the point bar inland to the slip off slope levee) ratio. If the meander amplitude is larger and the meander length smaller than Checker Channel, the length to width ratio will be closer to one.

4.3.3.3 Sedimentation rate on a submarine point bar

Sediment accumulation on the submarine point bar at Four Ways (Figure 4.20) was measured by placing aluminum pans in the sediment, and measuring the amount deposited weekly (section 3.2.9). Table 4.4 indicates the accumulation from 14 June to 16 August, 1977. A total of 5.3 cm was deposited, with the greatest amount of deposition occurring in June. It is of interest to compare sedimentation at the site and along the shoreline of a sand bar in Steamboat Channel, which accumulated only 1.6 cm of sediment during this same period (Table 4.4). The differing amounts can be partly attributed to the structural and discharge differences between Steamboat Channel and Four Ways. The principal difference is most likely the mode of deposition by which the sediment is deposited in the two channels. Steamboat Channel is a relatively straight channel and deposition along the sampling site would not be aided by helicoidal flow as is the case at the sampling site on Four Ways.

4.3.3.4 Meander scrolls and meander scroll depressions

Meander scroll depressions are evident in transects 11 (Figure 4.23) and 5C (Figure 4.24). These depressions provide a more hygric environment than the point bar crest. A soil

Table 4.4 : Sediment deposition (in mm) at sampling sites on Steamboat Channel and Four Ways.

	Steamboat Channel[1]			Four Ways
	12.0 m	9.0 m	6.5 m	
30 May 1977	-	28.0	20.0	
7 June	2.5	10.0	21.0	
14 June	5.5	11.0	11.0	12.0
21 June	2.0	1.0	3.0	13.5
6 July	1.0	1.0	2.5	8.0
12 July	-	2.0	3.5	2.0
19 July	-	1.0	1.5	2.0
26 July	1.0	1.0	1.0	3.0
2 August	2.0	1.5	--	4.0
8 August	1.0	1.0	--	4.0
16 August	1.0	.5	--	4.5
TOTAL	16.0	58.0	63.5	53.0

[1] Sediment pans were placed 12.0 m, 9.0 m and 6.5 m from the shoreline of the sand bar directly across Steamboat Channel from basecamp (Figure 4.20).

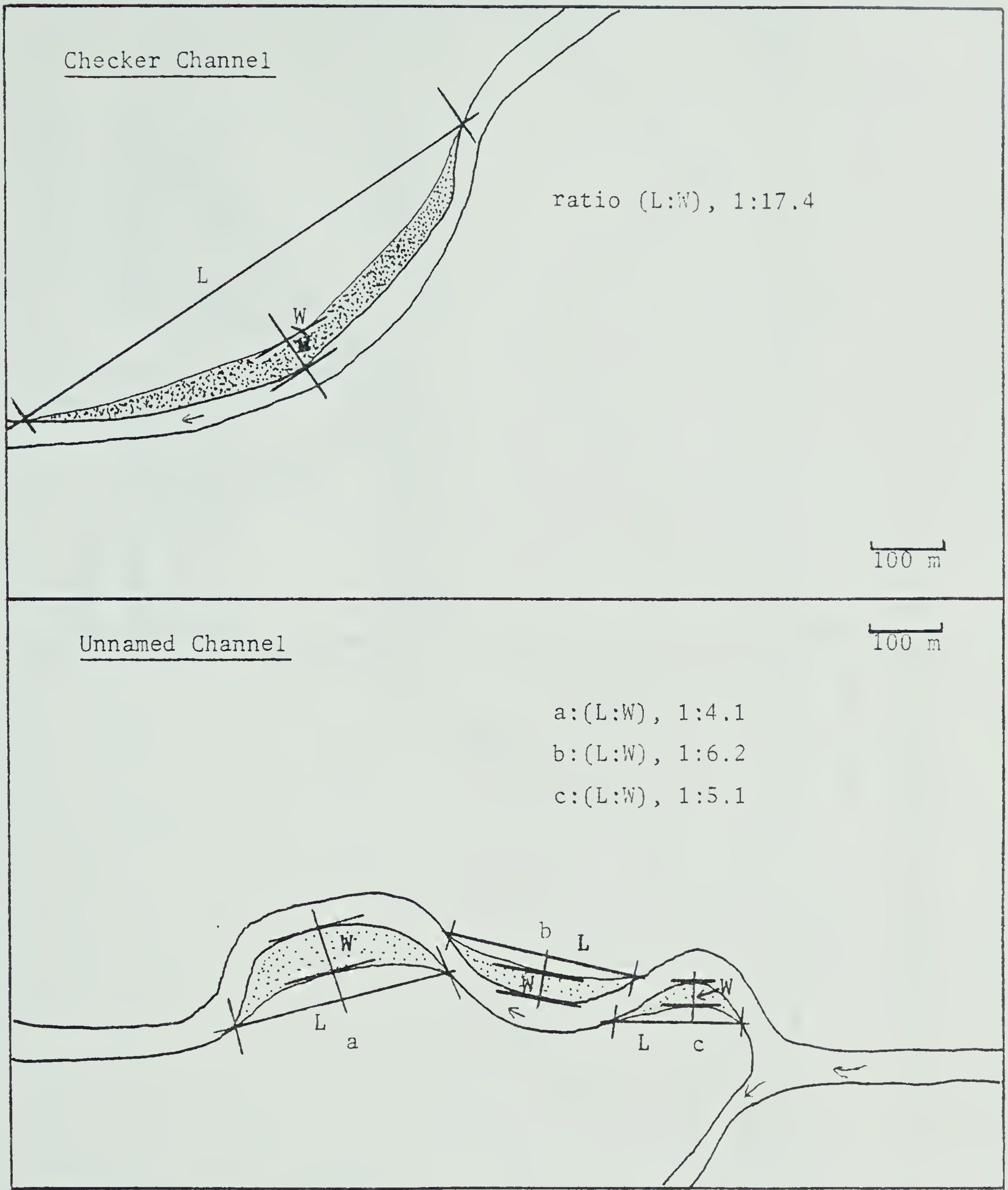


Figure 4.22 : Comparison of point bar length (L) to width (W) ratios between Checker Channel and the Unnamed Channel. The point bar vegetation consists of *Equisetum fluviatile* close to the water's edge and *Salix interior* somewhat closer to the slip-off slope levee inland.

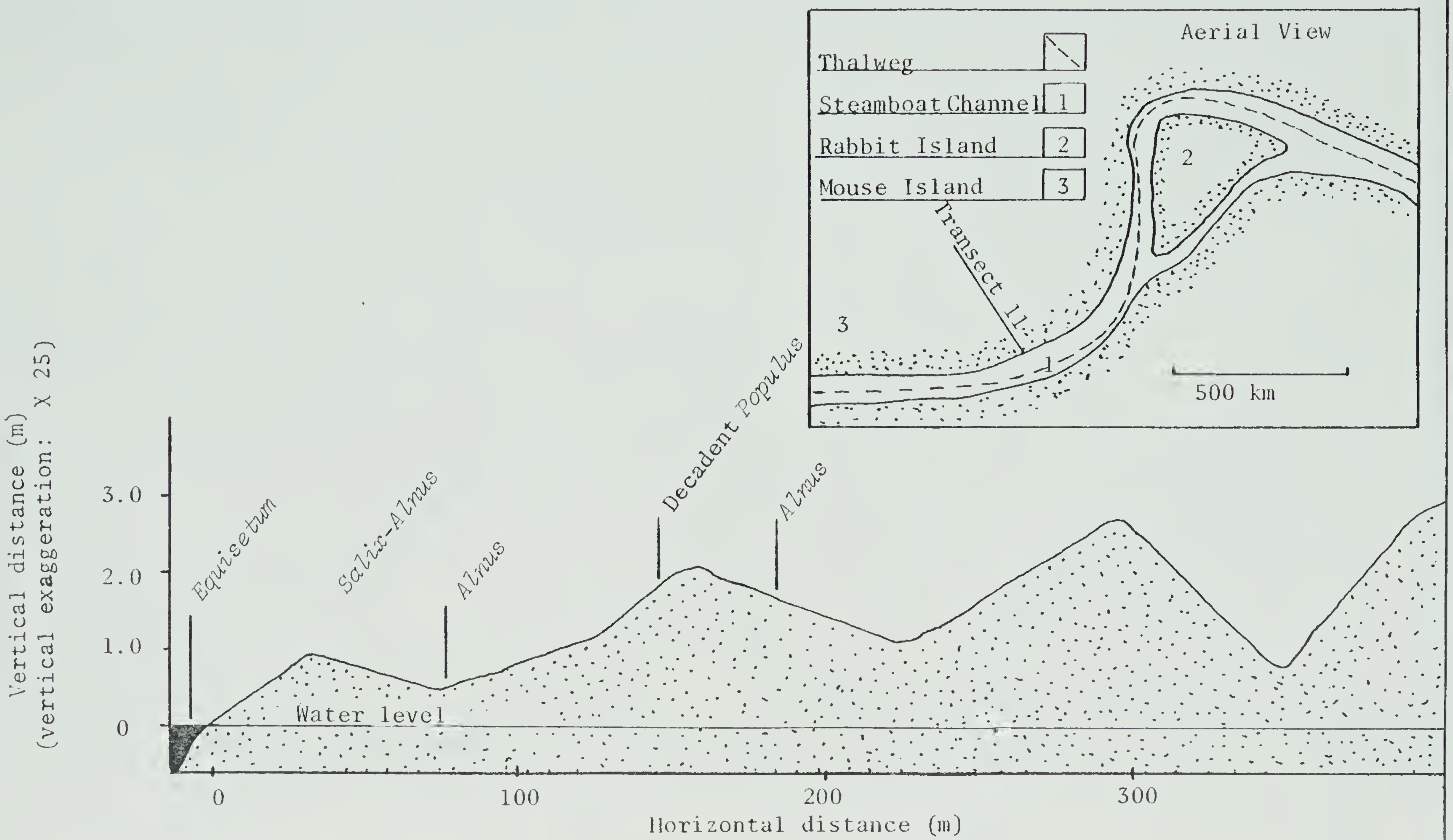


Figure 4.23: Transect 11, plant assemblages (sampled 7 July 1977).

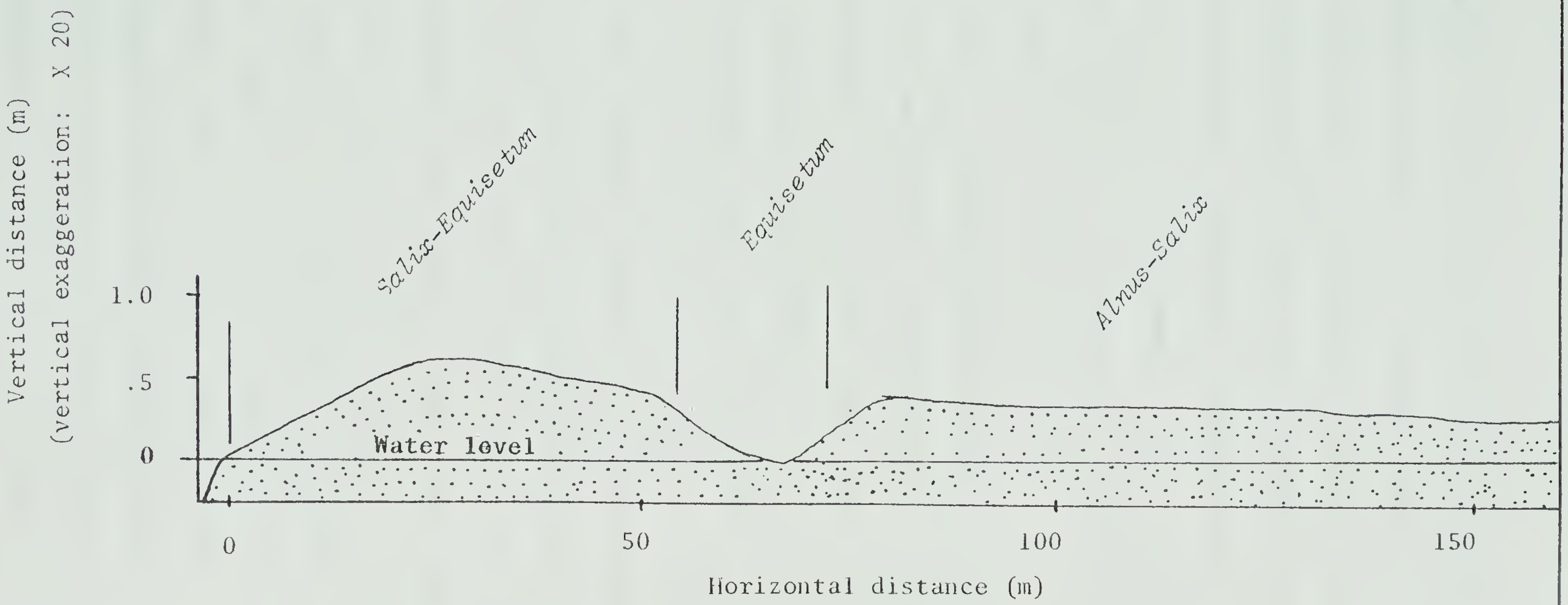


Figure 4.21: Transect 5C, Plant Assemblages (sampled 20 June 1977).
The convex formation inhabited by *Salix-Equisetum* is a meander scroll.

sample taken 20 cm from the surface at the centre of the meander scroll depression on transect 11 had a soil moisture content of 28% on 8 July 1977. On the same date, a soil sample taken 20 cm from the surface at the centre of the meander scroll had a 9% soil moisture content. The depression also has a cooler soil climate than the crest. The differences found in the soils in the meander scroll and meander scroll depression is not reflected in the vegetation composition of the sites. Both sites support Salix-Alnus assemblages.

Transect 5C demonstrates the same soil moisture characteristics as seen on transect 11. The depression had standing water (20 June 1977) averaging 0.1 m in depth. The crest of the point bar was dry and a soil sample taken approximately 20 cm from the surface at the centre of the meander scroll had a soil moisture content of 12%. It supports a sparse growth of *Salix interior, S. arbusculoides* and *Alnus tenuifolia*. The depression supports an *Equisetum* assemblage.

The meander scroll and depression along transect 5C suggests that the channel bordering the meander scroll was larger in the past when these features were formed. Reineck and Singh (1975) state that a large river is necessary for the formation of a meander scroll and depression sequence on the convex bank of a meander loop. The 1922 map of Blanchet (Figure 4.13) and the 1950 map compiled by Brown (Figure 4.14) indicate that this channel formed between 1922 and 1950. The 1950 map produced by Brown shows the channel width then ranged between 75 and 100 m. Presently the channel is 25 m in width.

Recently, geomorphic change in this portion of

the delta has resulted in the shifting of the thalweg so that the meander scroll is now being eroded.

The point bar developments along other channels in the delta lack meander scroll depressions and are typical 'small stream' point bar developments as described by Reineck and Singh (1975).

4.3.4 Sand bars

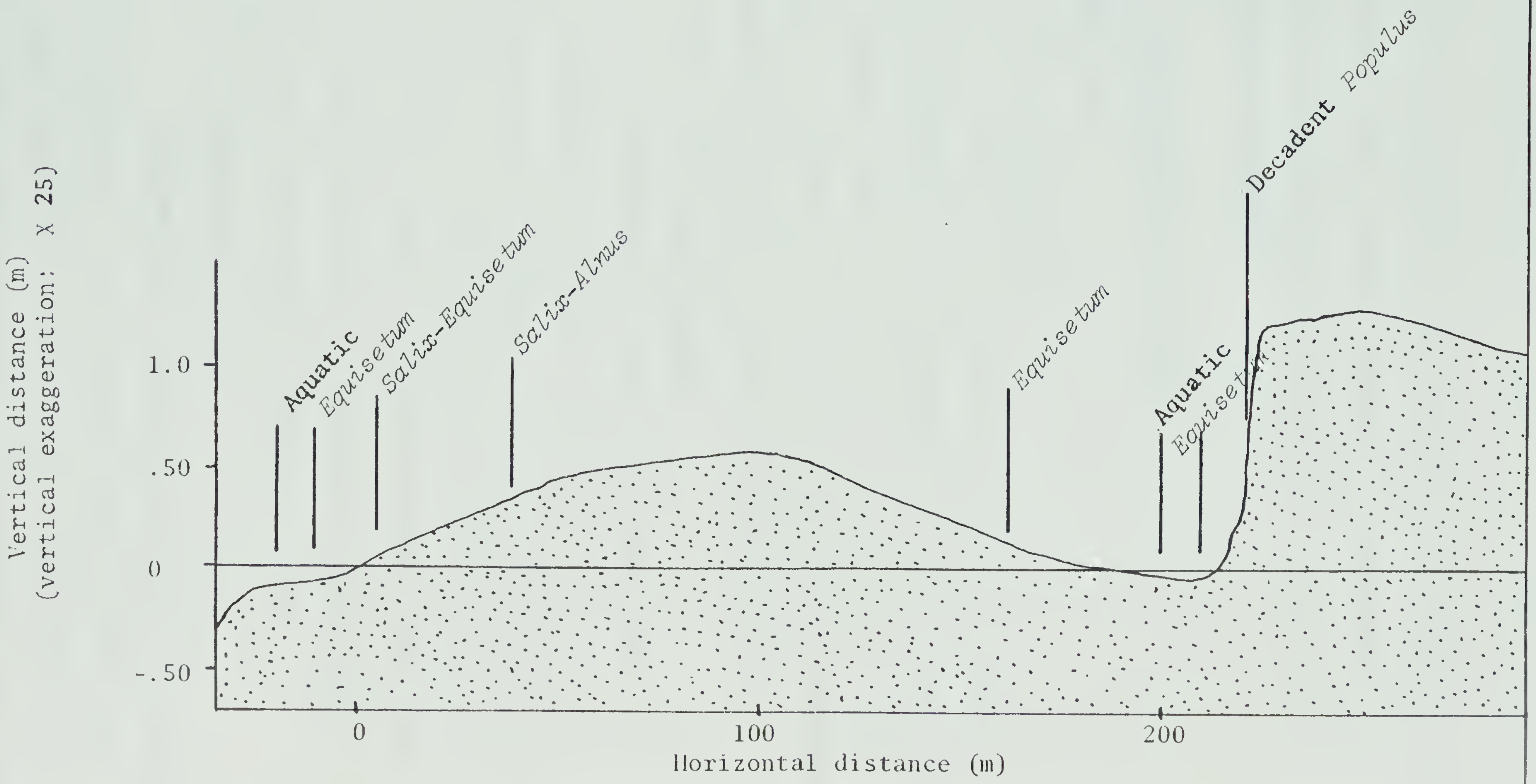
Sand bar construction is initiated by bedload deposition (Axelsson, 1967). The sand bar along transect 17 on Steamboat Channel (Figure 4.25) has developed over the past 27 years by the deposition of bedload during the spring floods. The deposition of sediment has been aided by driftwood that has been incorporated into the sand bar. A line of driftwood along the crest of the bar delineates an old water level that is assumed to have crested here about 20 years ago, before the growth of the *Alnus tenuifolia* (maximum age 14 years) and *Salix* spp. (maximum age 18 years) that inhabit the same portion of the sand bar began.

4.3.4.1 Deposition

Table 4.4 shows the amount of sediment deposition through the field season on the submerged portion of the sand bar along Steamboat Channel. Sediment deposition was greatest closest to shore; 6.35 cm during the field season. This is attributed to the effect of a dense growth of *Equisetum fluviatile* which grows as an emergent along this shore providing calmer water for the sediment to settle out. The other two sample sites located 9 m and 12 m from the

Figure 4.25: Transect 17, plant assemblages (sampled 9 August 1977).

The convex landform inhabited by a *Salix Alnus* assemblage is a developing sand bar. It began forming approximately 25 years B.P., when the abandoned cut bank levee presently inhabited by a Decadent *Populus* assemblage formed the left bank of Steamboat Channel.



shore, accumulated 5.8 cm and 1.6 cm of sediment respectively. The site accumulating 5.8 cm of sediment has only a sparse growth of *Equisetum* while the site farthest from shore has a sparse aquatic growth of *Potamogeton vaginatus*.

4.4 Regional geomorphology of the delta

4.4.1 Outer delta

4.4.1.1 Introduction

The Slave Delta can be divided into three well defined areas of geomorphological development; the outer delta, the mid delta and the apex. The outer delta can be divided into three different zones; the submarine delta, and two zones of the subaerial delta, the exposed zone and the protected zone (Figure 4.26).

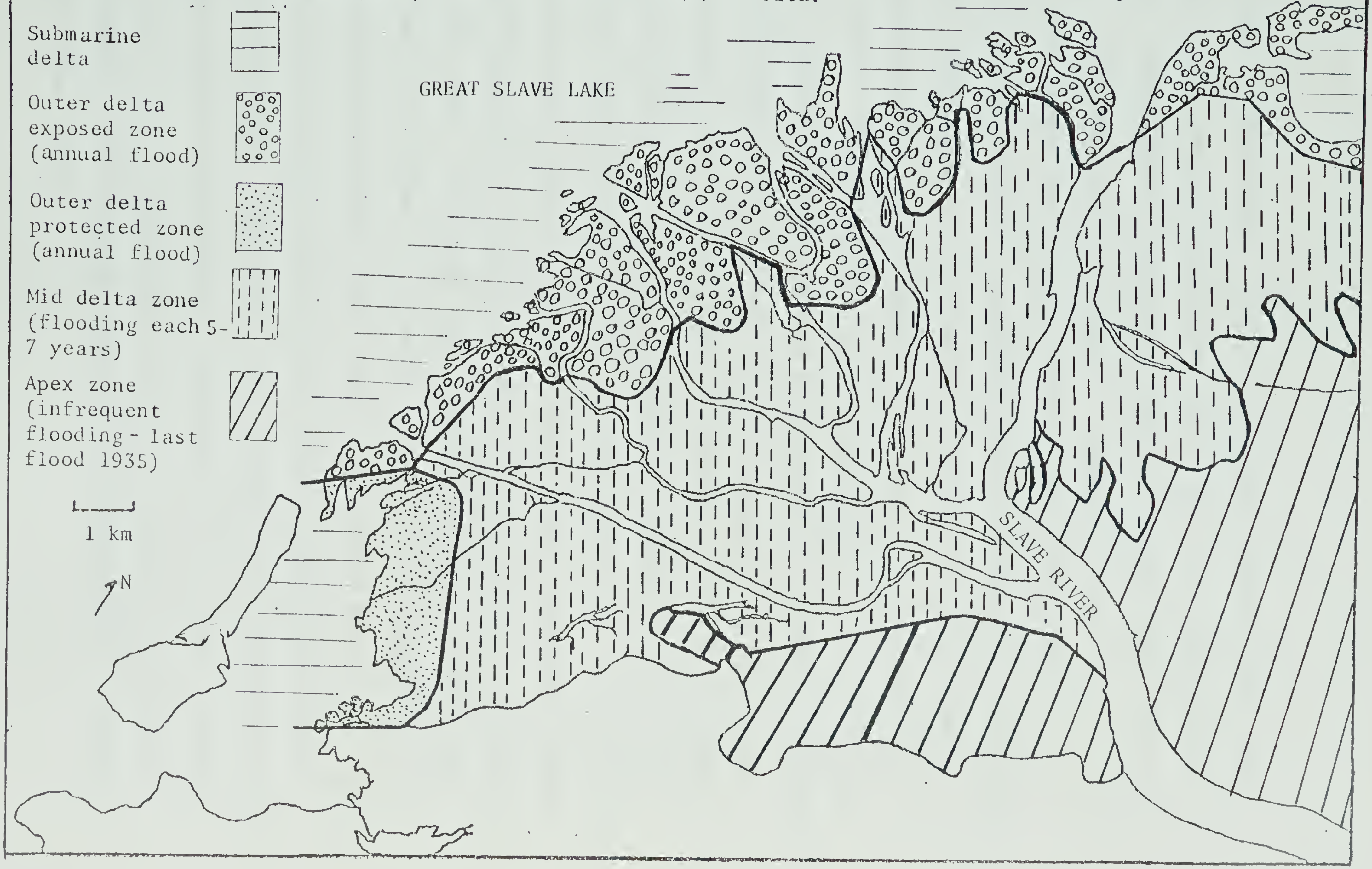
4.4.1.2 The submarine delta

The submarine or pro-delta area (Thakur and MacKay, 1973) is defined as the bedded structures of the bottomset, foreset, and topset bed. Of immediate importance to the progressive development of the outer subaerial delta, is the continued advance and buildup of the topset beds by sediment deposition. The topset beds provide the base for wave shoel and levee development and eventual cleavage bar island formation (Axelsson, 1967).

4.4.1.3 The protected zone

The protected zone of the outer delta comprises 6.0 km^2 or 5% of the delta. It is protected from the direct wave action of the lake by Moose Deer Island and its shoal that extends northward for 2 km from the northern tip of the island. Moose Deer

Figure 4.26; Flood frequency zones of the Slave River Delta.



Island is approximately 30 m (at the highest point) above the mean August 1977 water level of Great Slave Lake. The island supports a tall, close-crown coniferous and boreal mixed wood stands which provide additional protection to the section of delta that is in the lee of the island. The shoal is wavebuilt from delta sediments and supports an assemblage of *Salix interior, S. glauca, Carex aquatilis, Equisetum fluviatile,* and some *Typha latifolia* and *Sparganium multipedunculatum.* The shoal is stabilized by an accumulation of driftwood. The shoal and island act as a buffer to the lake's waves and effectively prevent removal of the sediment discharging from Nagle and Whiteman's Channel (Figure 4.20). The protection afforded by Moose Deer Island and its shoal is well illustrated by the birdsfoot delta has been very rapid as evidenced by comparison of Day's (1972) map and aerial photographs taken on 7 September 1977. The development of this small delta coincides with the growth of the wavebuilt shoal extending northward from Moose Deer Island. Prior to the construction of this shoal, the aquatic basin (defined presently by Moose Deer Island and its shoal to the northwest and west, the mainland to the south and the protected zone of the outer delta to the east and northeast) was relatively deep and very exposed to the erosive power of Great Slave Lake. This basin, which presently has an approximate mean depth (based on 25 readings, 5 August 1977) of 1.25 m and a maximum depth of 6 m, was deep enough in the 1920's to allow the passage of steamboats used to deliver supplies to Fort Resolution (J. Beaulieu, Pers. Comm., 1977).

A review of maps of the delta from 1922, 1950, 1971 and 1977 (Figures 4.13, 4.14, 4.15 and 4.16) reveals the progressive sedimentation of the basin within the protected zone. Subaerial build-up within the basin is primarily through an even accumulation of sediment during the spring flood. The subaerial alluvial deposits from the upstream area to the lake shore, display very little wavebuilt shoal or levee development, although the mouths of Nagle and Whiteman's channels have small levees.

4.4.1.3.1 Sedimentation

The basin within the protected zone is shallow and therefore adjusts rapidly to the temperature and therefore the density of incoming floodwater. Consequently sediment entering the basin should have a homopycnal deposition (Bates, 1953).

4.4.1.4 The exposed zone

The exposed zone of the outer delta is defined as the cleavage bar islands and wavebuilt shoals bordering Great Slave (Figure 4.26). This zone covers 24 km^2 or 20% of the delta and is the most aquatic location on the delta as 95% of it is at or below low summer water levels (Figure 2.3). The major geomorphic process operating on this portion of the outer delta is cleavage bar development (Dahlskog, 1972). As the delta expands into the lake, cleavage bars are formed at the mouths of active distributaries. Coarse fractions of the suspended sediment and bedload are deposited along submarine levees and eventually results in a significant buildup of sediment.

Dahlskog, *et al.* (1972) report that where lake

action dominates over river discharge the development of bars will dominate along one side of the channel mouth. Although wave action is an important force in the geomorphological development of the Slave Delta, the discharge current through the main channel offsets the dominating effect of wave action in cleavage bar formation. This is illustrated by Plate 9 which shows the sediment plume discharging from Steamboat Channel and curving north into the lake.

The bulk of sediment deposition on submarine levees occurs during spring (Dahlskog, *et al.*, 1972) as the sediment load increases markedly at this time (Figure 4.11). During this brief portion of the year, the river flood surge dominates over lake action as the lake is still largely ice covered. For the remainder of the ice-free year, the discharge of the Slave River continues to drop and the dominating geomorphological agent shaping the outer delta is therefore wave action.

The development of cleavage bar islands is of major importance to the continued progradation and high productivity of the Slave Delta. They lay the foundation for island development as they gradually build up over years of sediment deposition. A description of cleavage bar evolution and plant development on them is important in understanding the ecology of the delta.

Figure 4.27 illustrates the genesis of a cleavage bar at the mouth of Steamboat Channel. The submerged levee is forming in a V-shape thus the term cleavage. The build-up of the submerged levee is due largely to the deposition of bedload during the

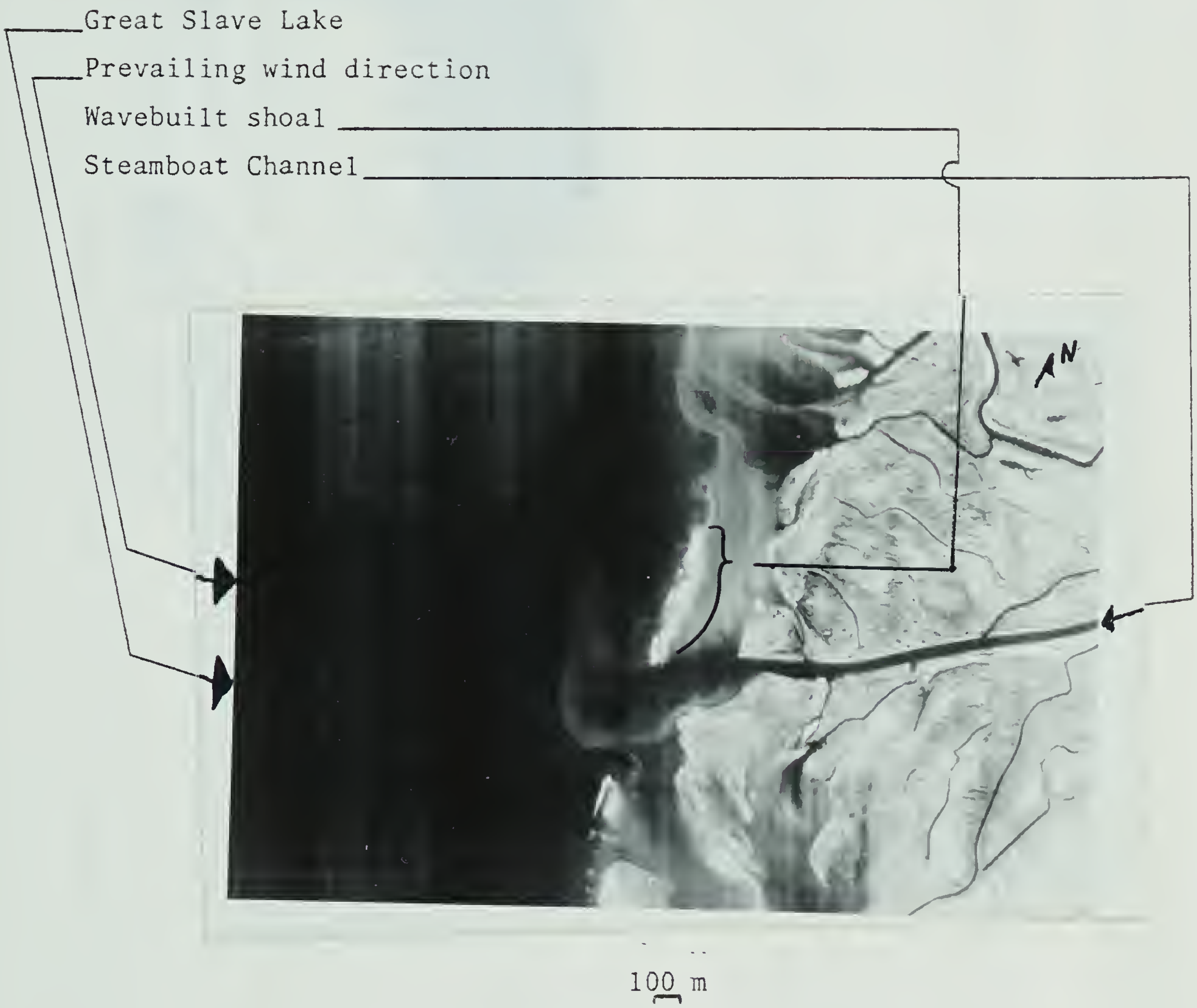


Plate 9 : Interaction between discharging sediment from Steamboat Channel combined with the prevailing wind direction form wave built shoals along portions of the outer delta. Thermal infrared photography taken 7 September 1977.

Courtesy, Canadian Wildlife Service.

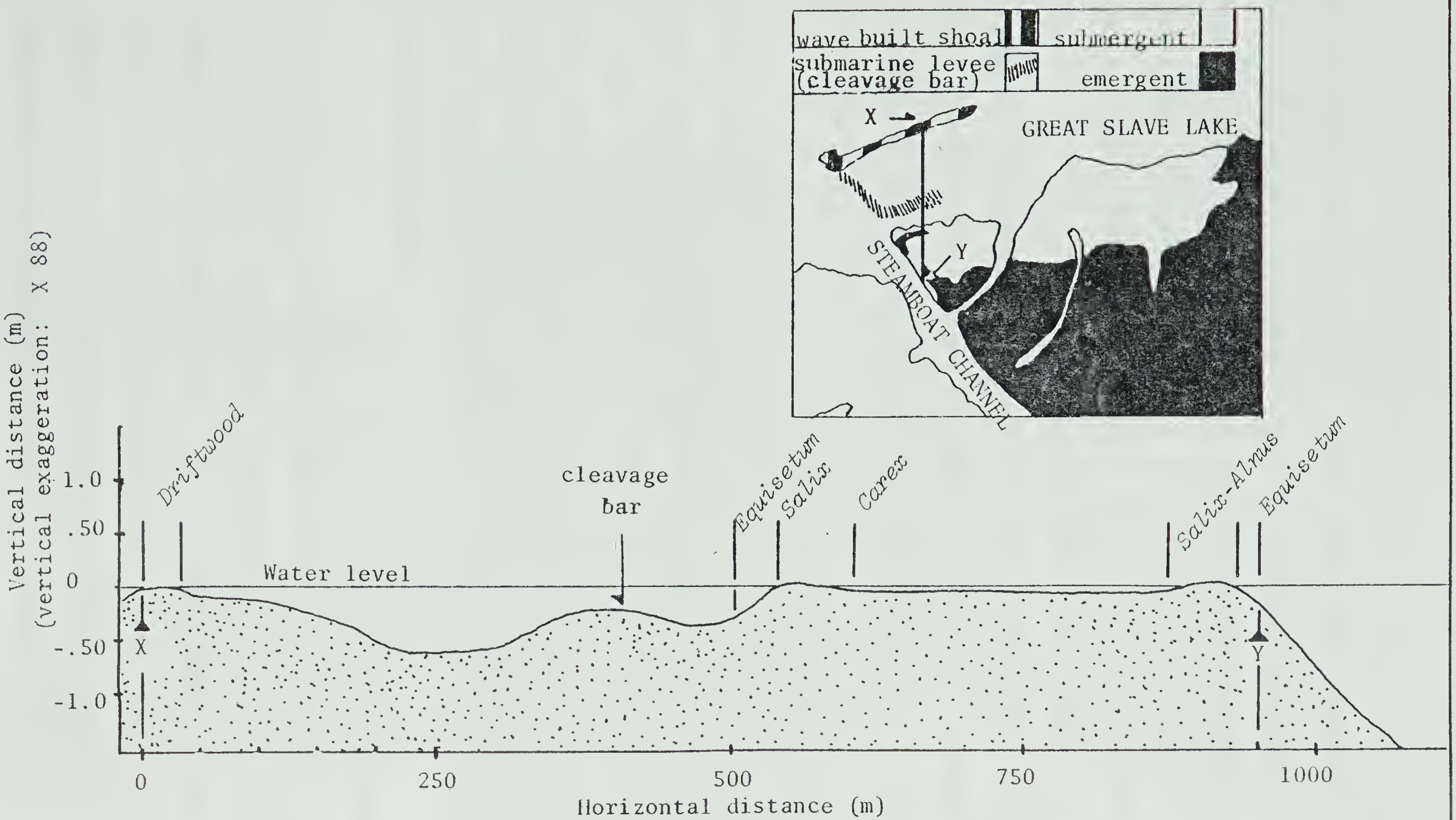


Figure 4.27: Transect 14, illustrating plant assemblages and submarine cleavage bar genesis at the mouth of Steamboat Channel (sampled 18 July 1977).

spring flood (Dahlskog, *et al.*, 1972). When the levee builds up to a sufficient height, driftwood lodges on it and stabilization occurs, followed by the invasion of pioneer species of aquatic and emergent vegetation. The upstream portion of the bar matures first and *Salix* species invade which further stabilizes the cleavage bar levee.

Continued development of this deposit into an island may be aided by the construction of a wave built shoal along the open end of the V-shaped cleavage bar, as shown in Figure 4.27. Accumulation of driftwood (Plate 10) on these shoals aids in stabilizing them.

The wave built shoal along transect 14 (Plate 11) acts as a buffer to the erosive action of the lake by protecting the aquatic area between the shoal and this island. This is illustrated by secchi disc readings taken 10 July 1977. Depths lakeward of the shoal ranged between 7 and 11 cm while the protected area had an average reading of 35 cm. Reduced turbidity enables aquatic vegetation to grow in the protected area, as shown by the establishment of *Potamogeton vaginatus*.

In some cases protection from the erosive action of the lake is provided by the construction of one or more levees such that they partially (Plate 12) or completely (Plate 13) seal off the open end of the cleavage bar. Along the lake front, driftwood carried down by the Slave River plays an important role in stabilizing these landforms (Plate 14). The duration of cleavage bar development from the submarine levee stage to cleavage bar island status can be

Plate 10 : Driftwood promotes the development of wavebuilt shoal formation (16 July 1977).
This shoal is illustrated in Plate 11.

Plate 11 ; Aerial oblique photograph of the wavebuilt shoal shown in Plate 10 (21 July 1978).

Courtesy D. Gill

100 m

Plate 12: Panchromatic aerial photograph of a cleavage bar island on the outer delta. This island is still partially open at the lake side (arrow) but submarine levees that are forming from each of the open ends will soon build up and close the cleavage (7 September 1977).

Courtesy Canadian Wildlife Service.

100 m

Plate 13: Panchromatic aerial photograph of Gabe's Island. This complex of cleavage bar islands is in the final stages of being closed off from the lake. Levees along the outer portions of the island are inhabited by the *Salix-Equisetum* assemblage while interlevee depressions are occupied by an *Equisetum* assemblage (7 September 1977).

Courtesy Canadian Wildlife Service.

Plate 14 : Driftwood accumulation along the outer levees of the cleavage bar islands protects the developing islands from wave action. The levees are further stabilized by pioneer species of *Salix interior* and *Equisetum fluviatile* (right centre of photograph) 16 July 1977.

estimated by investigating the development of Gabes Island (Figure 4.20). Comparison of the collection of available maps (Figures 4.13, 4.14 and 4.15) reveals the upstream portion was above the low summer water levels in 1922. The two diverging arms of the cleavage bar were invaded by *Salix* species in approximately 1932, according to tree ring analysis. Tree ring analysis indicates the levees bordering Great Slave Lake were invaded by *Salix* species in approximately 1963.

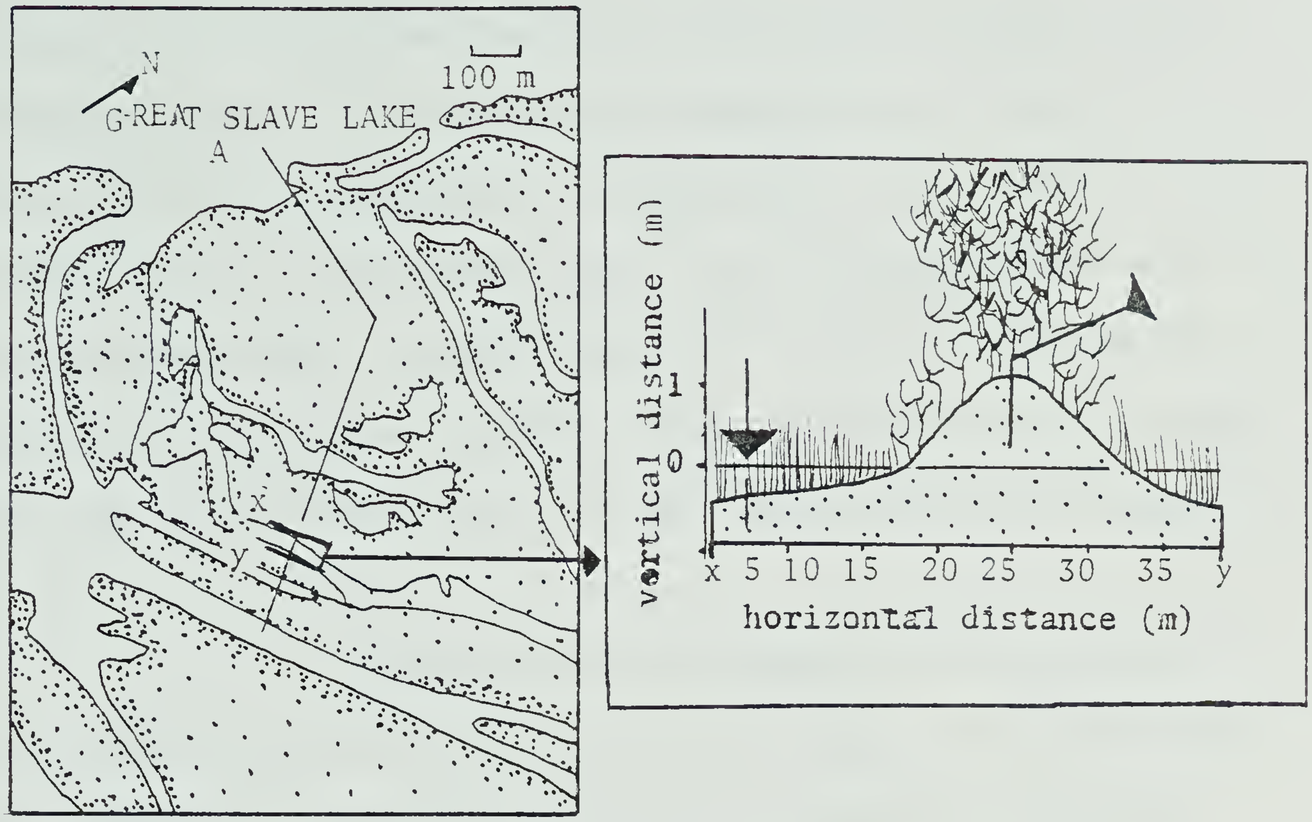
The development of Gabes Island took place over a 52 year period. It was effectively closed off from wave erosion of Great Slave Lake within the last 6 years (comparing Figure 4.15 and 4.16).

The more stable portions of the cleavage bar island, notably the original upstream levees, provide ideal habitat for *Alnus tenuifolia* and *Salix* species. The dense growth shades the ground sufficiently such that soil frost was still present 0.6 m below the elevated surface of the levee (Figure 4.1) on 13 July 1977. Figure 4.28 illustrates the differences in soil temperatures between the elevated levee and a site 18.5 m away in the interlevee depression. Soil frost was also encountered in the older levees of other cleavage bars during July.

4.4.2 Mid delta

4.4.2.1 Introduction

The area defined as the mid delta is the largest section of the Slave Delta, covering 54 km^2 or approximately 45% (Figure 4.26). This portion of the delta is transitional between the



A: Transect 12

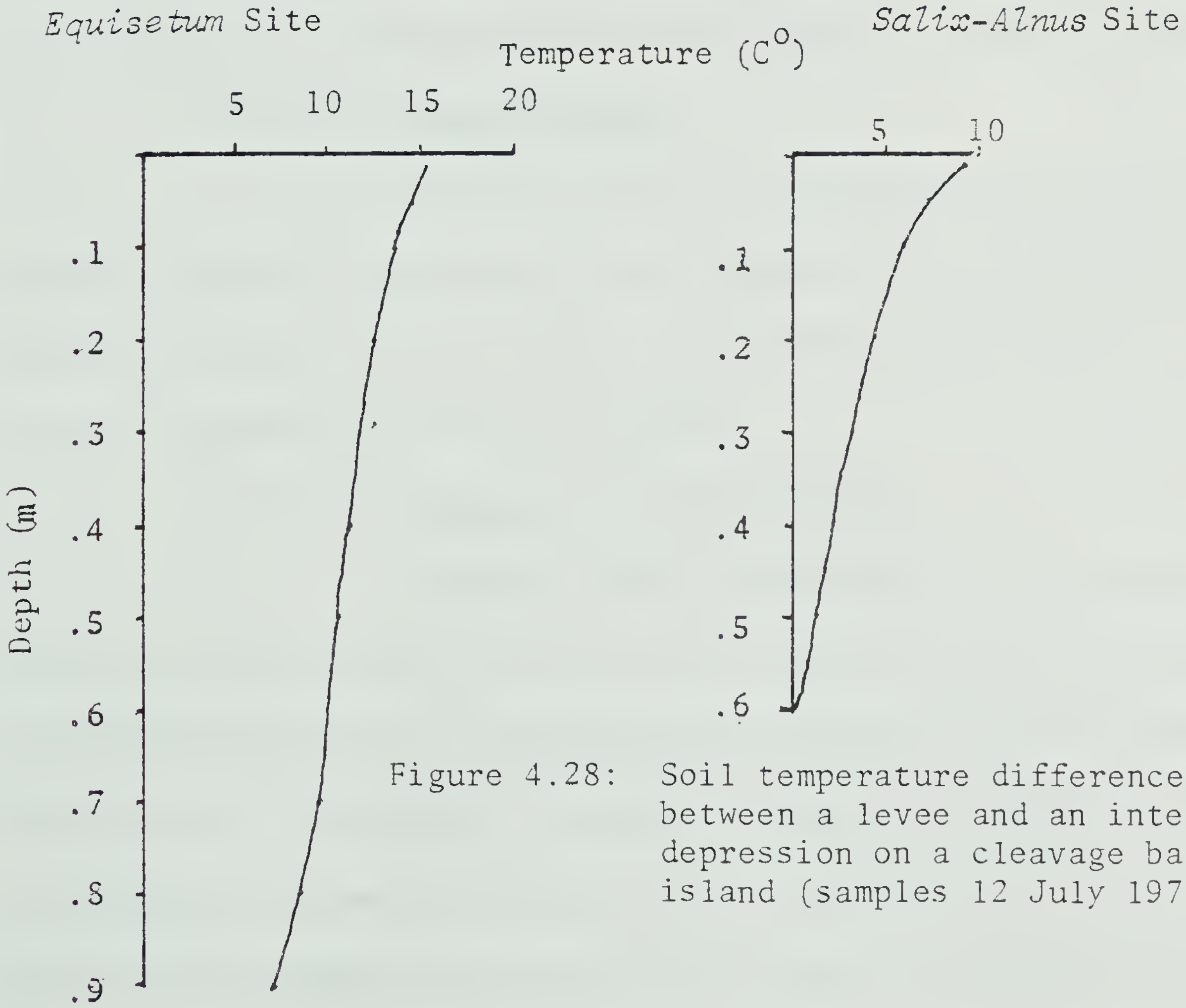


Figure 4.28: Soil temperature differences between a levee and an interlevee depression on a cleavage bar island (samples 12 July 1978).

youthful outer section and the mature apex portion upstream. The downstream margins of the mid delta resemble the outer delta, but unlike its youthful counterpart, the mid delta is not subject to the erosional forces of Great Slave Lake. Also, being more elevated, it is considerably dryer. Approximately 50% of the mid delta (most of which is in the upstream section) is above the mean June 1977 water level. By contrast only some 5% of the outer delta is above this level.

Channels that have been cut off by closure (Axelsson, 1967) provide most of the water bodies of the mid delta zone. Historical documentation of the development of the delta (Figures 4.13-4.16) illustrates that shifting, closure and formation of new channel has frequently occurred during the past five decades.

4.4.2.2 Channel closure

As this process is common in the Slave Delta, several transects were placed across channels in varying degrees of closure in order to see if there is environmental/ecological change on these landforms as closure proceeds.

4.4.2.3 Processes causing closure

Axelsson (1967) and Einstein (1972) explain the closure of distributaries in terms of disruption of the energy gradient by channel elongation. The transportive capacity of the channel diminishes as it increases in length, causing an accelerated deposition of suspended sediment and bedload. The reduction of energy available to move the sediment may be due to the formation of another distribu-

tary's former path. The lodging of driftwood along distributaries undergoing closure further aids the accumulation of sediment.

4.4.2.4 Closure in the Slave Delta

Three small, northwest-southeast oriented channels on Mouse Island in various stages of closure were studied (Figure 4.29). All three channels appear to have transported only minor amounts of sediment when they were active according to previous maps of the delta (Figures 4.13-4.16).

Channel A is 50 m inland from Steamboat Channel and has long been cut off from the river. It is not known when this channel was active, as the earliest map available (1922) does not show it. The shape of this channel suggests a prolonged period of separation from Steamboat Channel as its levees have eroded and its bed has filled in to the point where it is difficult to accurately distinguish channel morphology. Channel B has only recently been closed off from Steamboat Channel, and Channel C is still open, as shown in Figure 4.30.

Channel abandonment appears to have noticeable effects upon the environment of both point bars and levees on the channels studied. The gradual exclusion of standing water in the channel bed as the landforms are built up by deposition of sediment during flood periods promotes warmer ground temperatures. Both the point bar and levee environments of Channel A are noticeably warmer than Channel C (Figures 4.31 and 4.32). Incoming solar radiation can be readily absorbed by the dry bed of Channel A, thereby raising soil

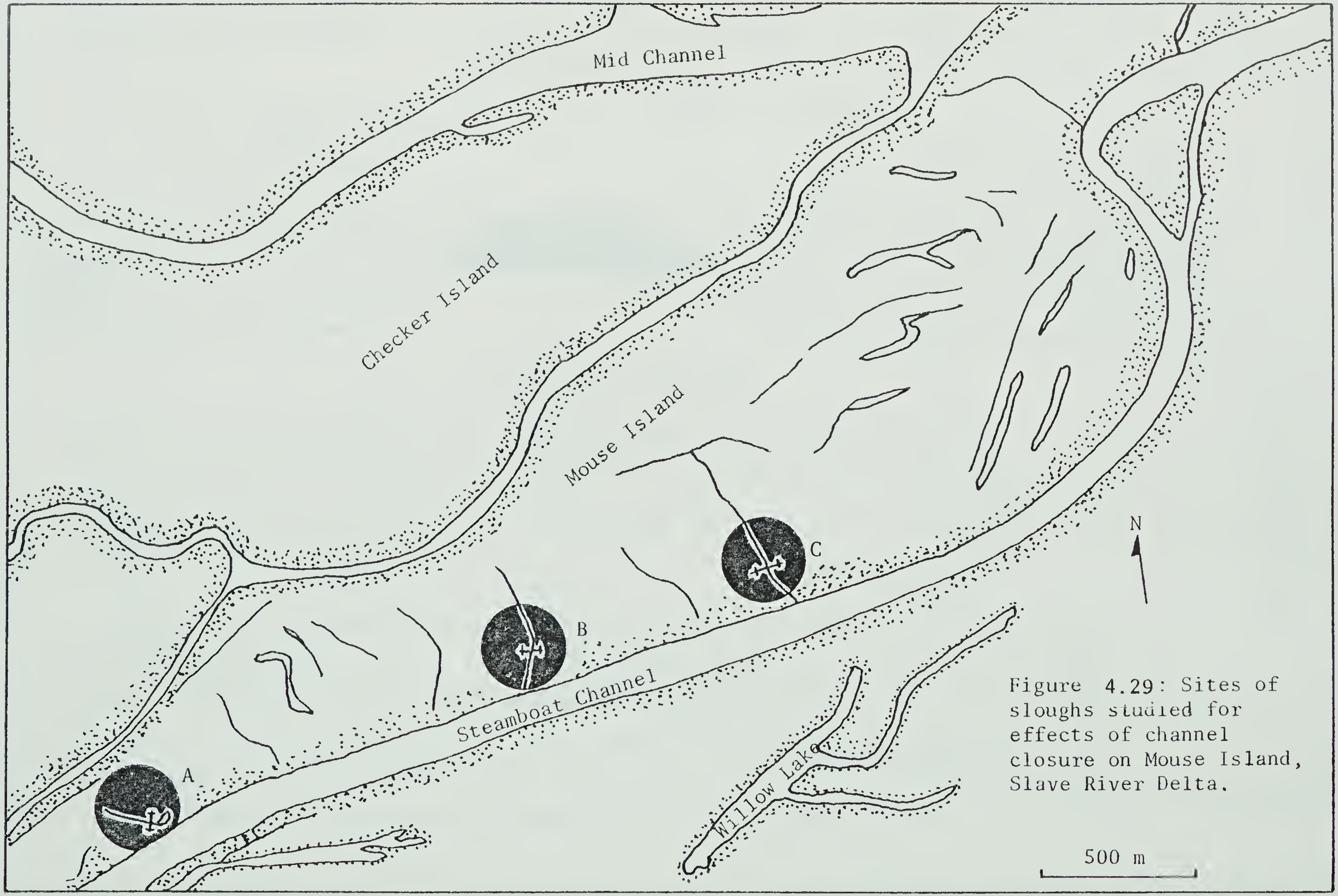


Figure 4.29: Sites of sloughs studied for effects of channel closure on Mouse Island, Slave River Delta.

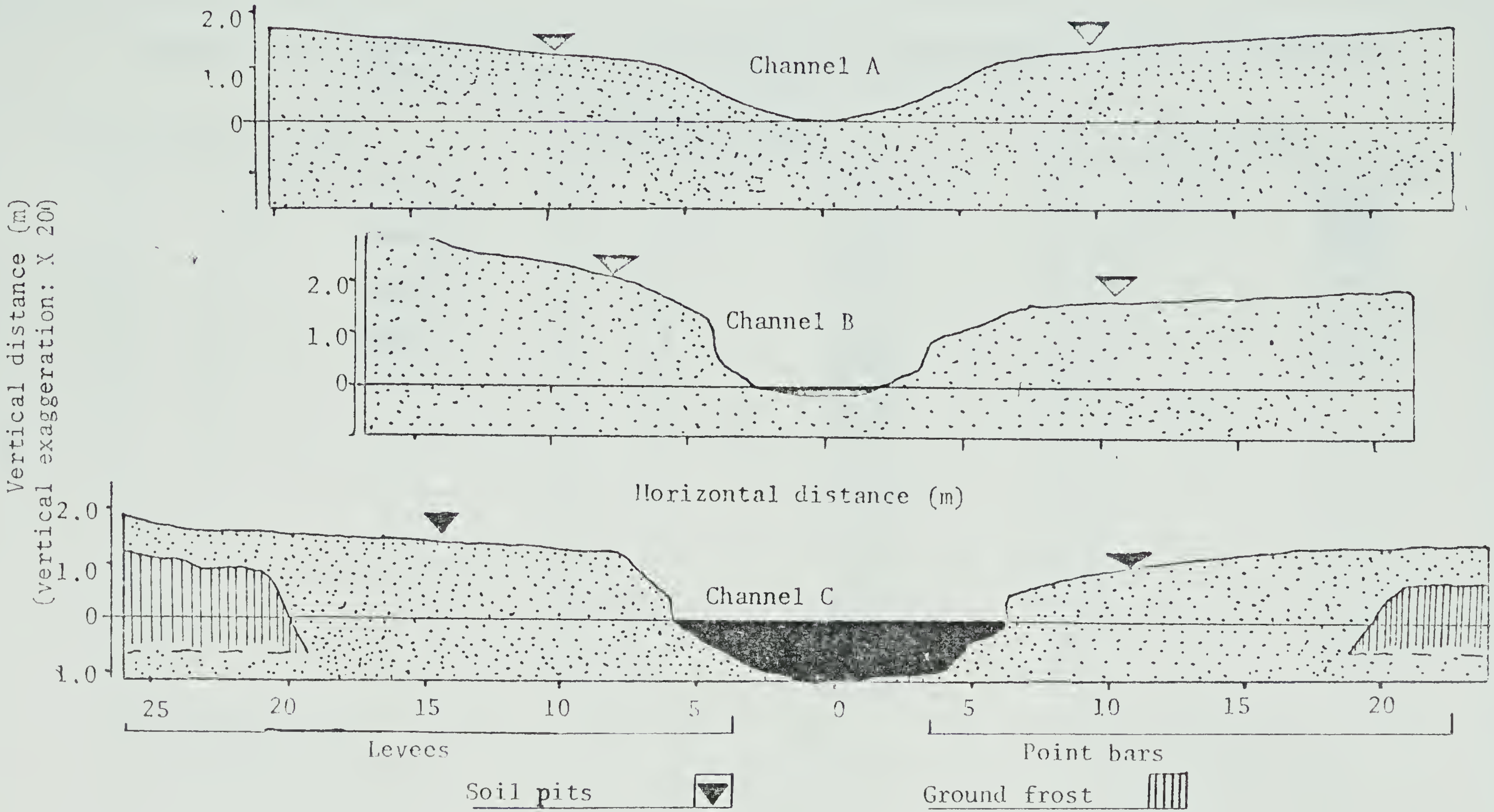


Figure 4.30: Profiles of channels in various stages of abandonment.

A. Channel sealed off from direct contact with Steamboat Channel for at least 50 years.

B. Channel recently sealed off from direct contact with Steamboat Channel.

C. Channel with one end open to Steamboat Channel.

Figure 4.31: Temperature and soil profiles for the levees sampled along the abandoned channels on Mouse Island (sampled 3 August 1977).

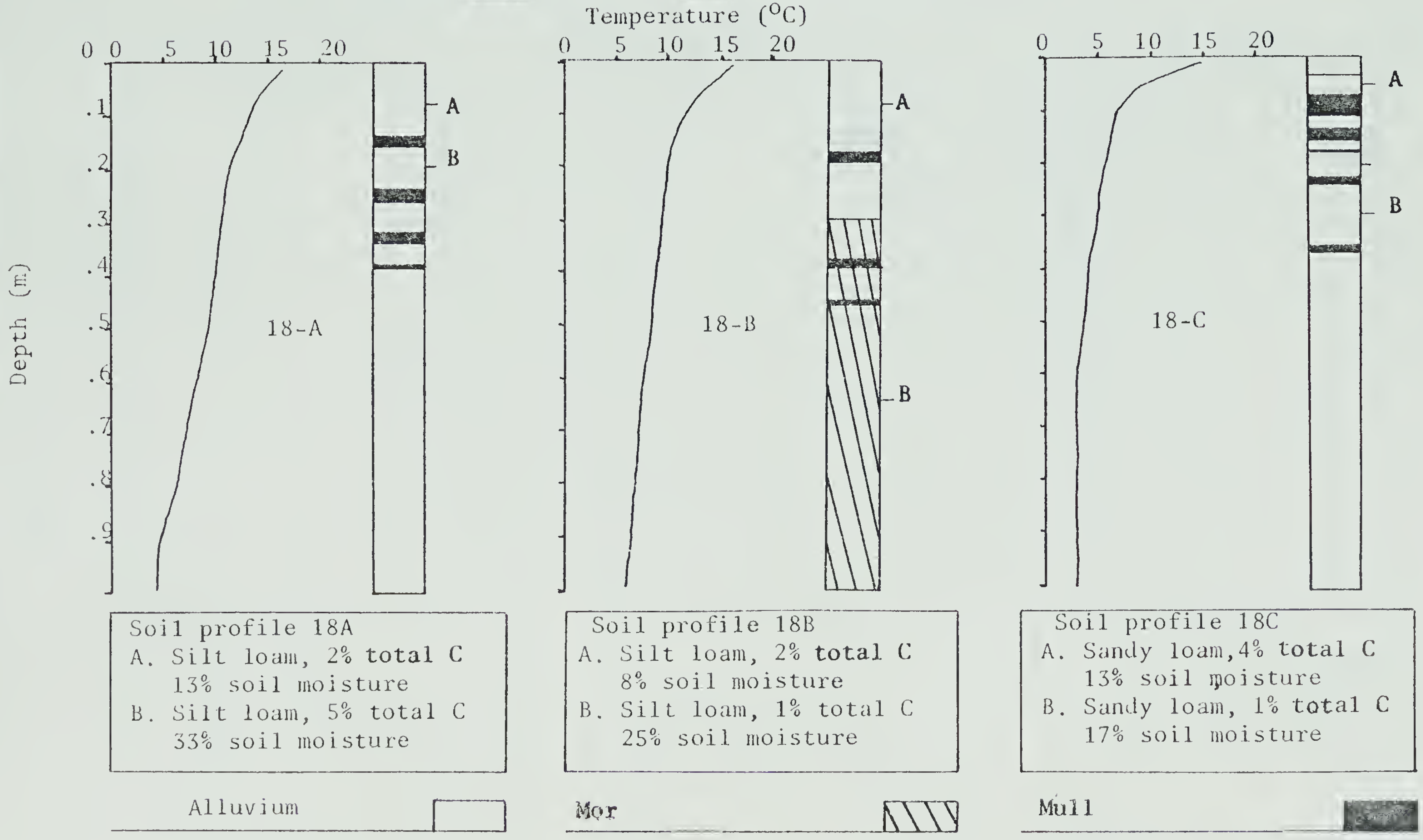
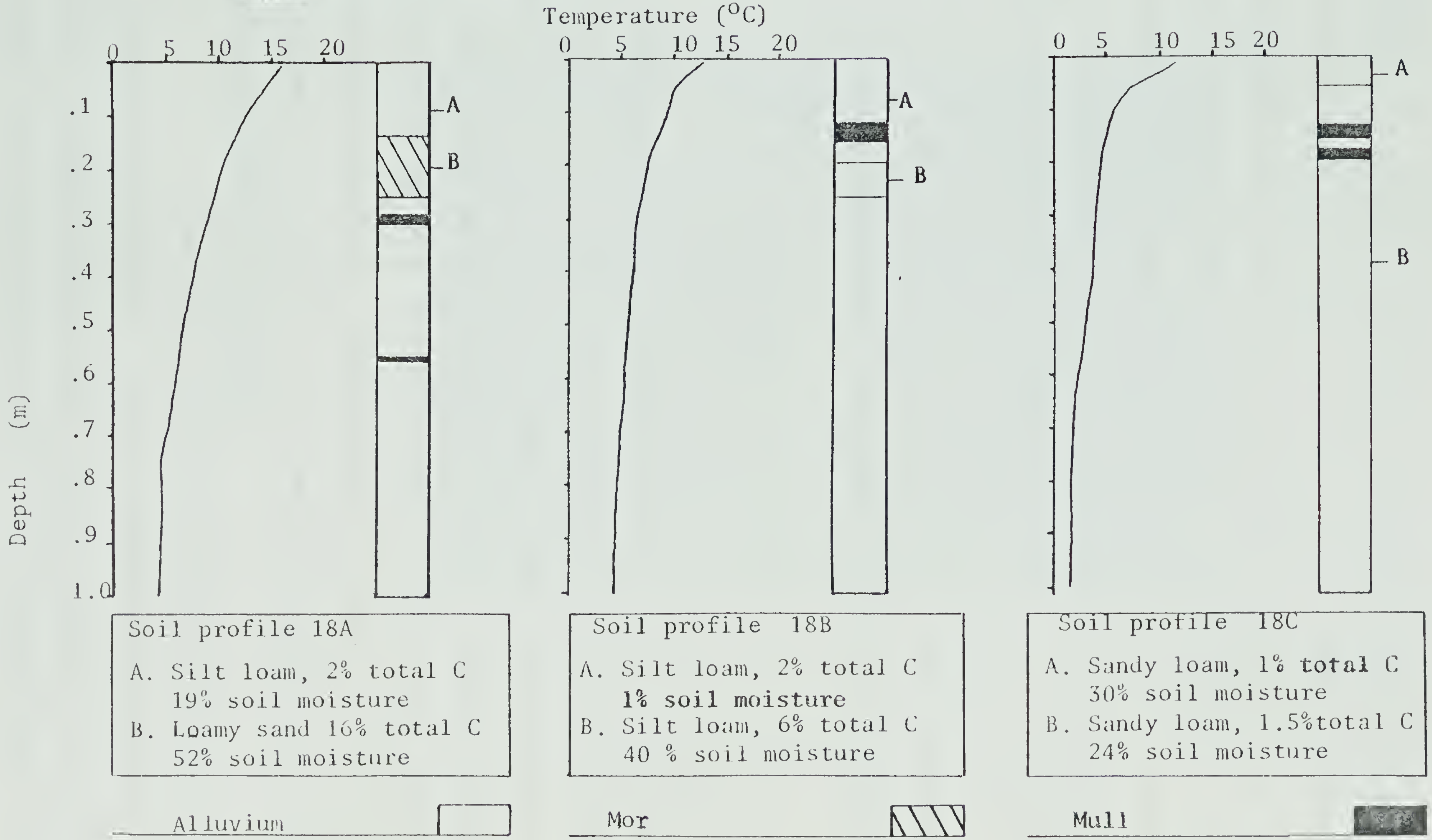


Figure 4.32: Temperature and soil profiles for point bars sampled along abandoned channels on Mouse Island.



temperatures. Channel C, still open to Steamboat Channel has a great deal of standing water. Since water has a specific heat absorption capacity greater than that of land, the channel bed of C will not experience the heating effect of the sun as noted on Channel A. As vegetation assemblages and their structure do not vary much between levees, or between point bars of the three channels, the absence of standing water in the channels appears to be the chief factor responsible for the warmer environment of Channel A. Ground frost was present in the levees along Channel C attesting to cooler environment apparently created/maintained by the standing water in the channel.

4.4.3 Apex

4.4.3.1 Introduction

The apex zone constitutes a relatively small portion of the study area and is inhabited chiefly by *Picea* and *Populus* assemblages (Plates 15, 16). The outstanding characteristic differentiating this portion of the delta from the outer delta and mid delta is the lack of flooding due to greater elevation. Absence of flooding has encouraged development of a white spruce (*Picea glauca*) forest and a thick feather moss growth. Establishment of spruce and feather moss has sufficiently insulated the soil, promoting a negative heat balance and subsequent invasion of permafrost.

The other distinguishing physical features of the apex zone are cut off channels. These abandoned channels provide habitat for a variety of aquatic and emergent vegetation during the early summer when local snowmelt water occupies the old channel bed.

Plate 15: *Picea* assemblage along Transect 4, north of Nagle Channel near the Apex.

Plate 16: *Populus* assemblage illustrating a dense layer of *Equisetum arvense*.

These sloughs have bottoms of fine silt and clay which help to perch water in these channels into mid summer. The ecology of these seasonally ponded sloughs is discussed in Section 5.5.4.

4.4.3.2 Permafrost

Permafrost in northern deltas usually develops after the landform has gained sufficient elevation through deposition such that flooding finally becomes irregular. Once sedimentation is no longer a constraint to growth, an insulating bryophyte layer begins to develop. This layer grows in thickness until a negative heat balance becomes established in the soil which prevents thawing of the seasonally frozen ground. Brown (1974) describes the influence of the moss layer on the thermal exchange between the ground and the air which leads to the formation of permafrost; Gill (1978a) discusses how this process functions in the Mackenzie Delta.

4.4.3.2.1 Bryophyte-soil frost relationships

Significant growth of bryophytes is limited to the apex zone. The thick layer of moss growing in these *Picea* stands is an effective insulator. Figures 4.33 and 4.34 illustrate the range of depths to frost in two different *Picea* stands in the apex zone, north of Nagle Channel. Although the depth to frost measurements were taken too early (29 July for transect 16 and 9 August for transect 4) to be certain about the distribution of permafrost, the depth to frost measurements (as shown in Figures 4.33 and 4.34) are indicative of permafrost distribution.

Picea glauca in the climax stand along

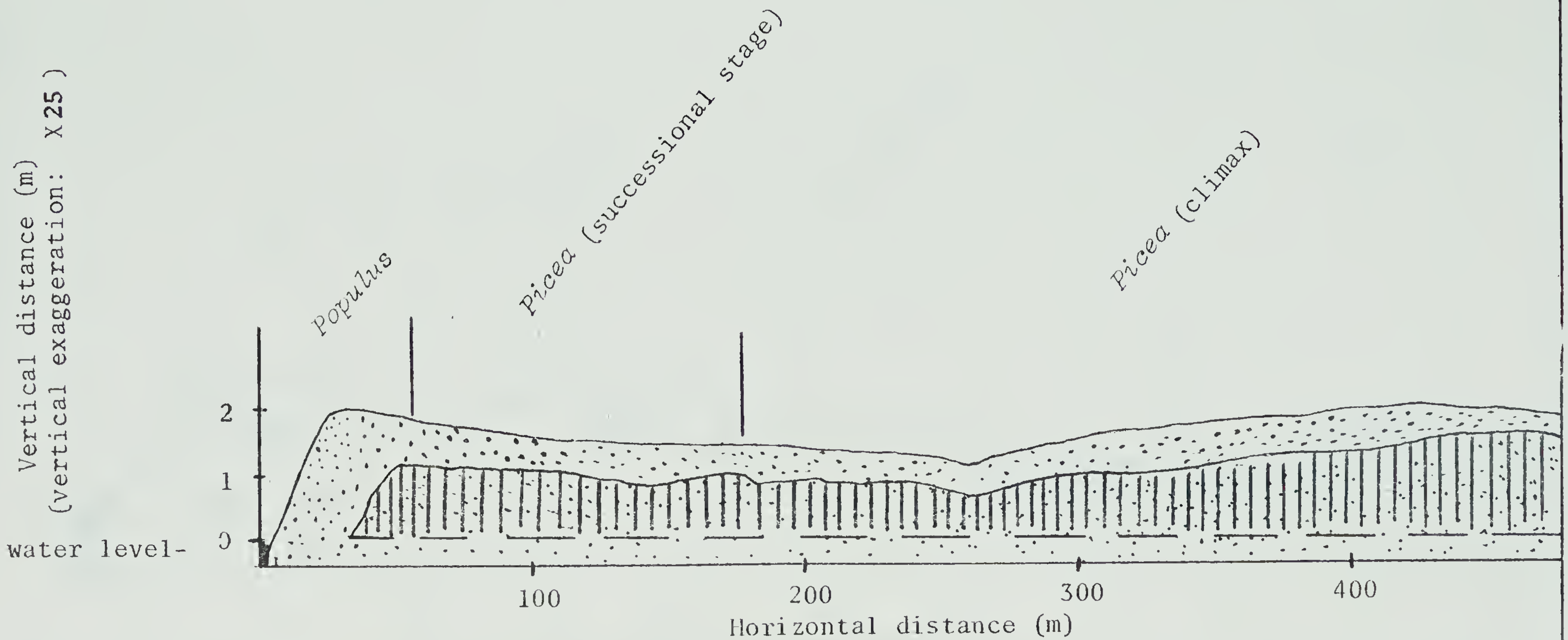


Figure 4.33:Transect 16. Plant Assemblages sampled (29 July 1977), north of Nagle Channel in the apex zone.

Groundfrost: ( )

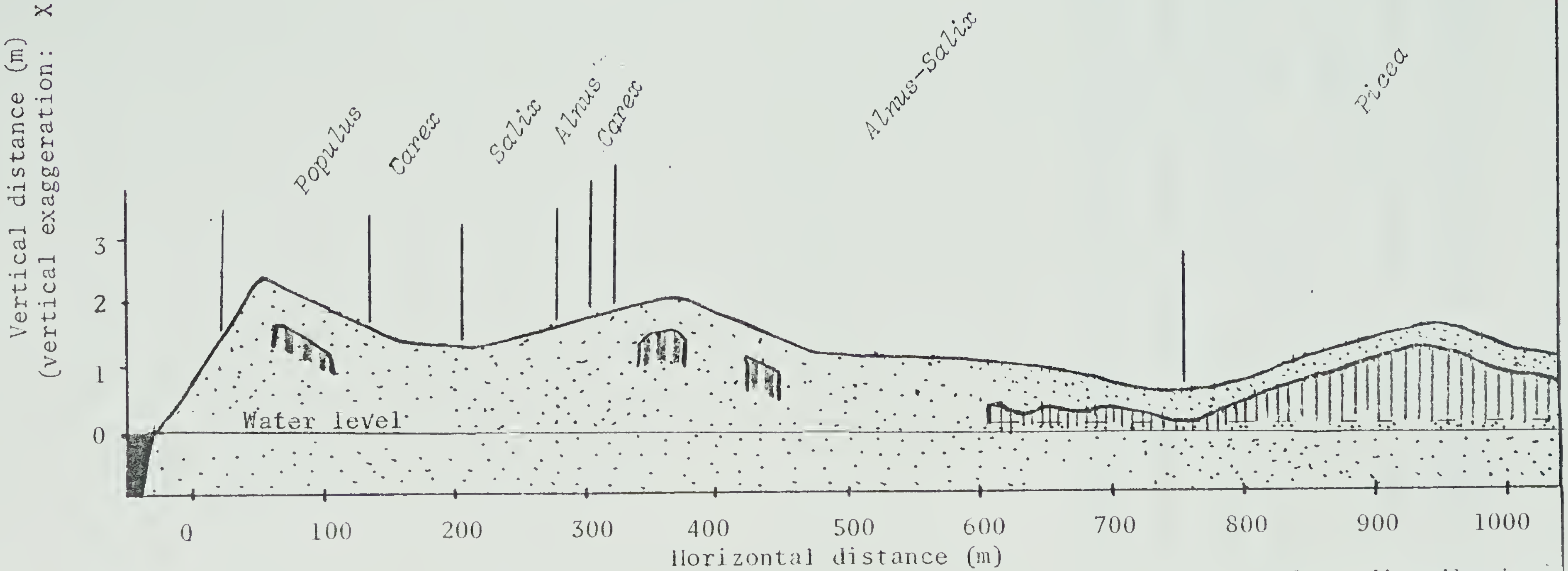


Figure 4.34: Transect 4. Plant assemblages (sampled 12, 13, 14 June 1977) and permafrost distribution (sampled 9 August 1977) in the apex zone north of Nagle Channel. The scattered ground-frost ( ) may disappear entirely during the duration of the summer. The permafrost ( ) in the Picea assemblage is a product of the very thick bryophyte layer.

transect 16 reach a maximum age of 143 years. The maximum age of the climax stand along transect 4 is 232 years. The thickness of feather-moss along Transect 16 averages 6 cm (n = 20) while moss along Transect 4 averages 16 cm (n = 25). The difference in the thickness of the moss layers is reflected in the depth to frost. The mean depth (30 July 1977) along Transect 16 under a thin moss cover was 45 cm (s = 7 cm), while Transect 4 with a thick moss layer had a mean depth of 29 cm (s = 8 cm).

CHAPTER FIVE

VEGETATION

5.1 Introduction

This study classifies the vegetation of the Slave River Delta into 12 plant assemblages. In this chapter the different assemblages are described in terms of distribution, environment, vegetation analysis and successional trends.

5.2 Vegetation map

The vegetation map (Figure 5.1) shows the distribution of the 12 plant assemblages. The *Picea* assemblage is divided into mature climax stands and youthful successional stands.

5.3 Assemblages table

The Assemblages table (Table 5.1) demonstrates the cover-abundance of species present in each assemblage. The assemblages are ranked from left to right in relation to their soil moisture or hygrotope class (Table 5.2) which is indicated at the top of Table 5.1. The most aquatic assemblage is placed at the left and the most elevated, least flooded assemblage is on the right. Plants in the species column are arranged in similar order, with aquatic species listed at the top and species occupying mesic habitats near the middle of the column. The less significant and rare species and are included in the lower half of the column, followed by bryophytes at the bottom.

Table 5.2 Hygrotope class.

Designation	
1	<5% soil moisture
2	5-9% soil moisture
3	10-14% soil moisture
4	15-24% soil moisture
5	25-29% soil moisture
6	30-40% soil moisture
7	> 40% soil moisture
8	≤ 5.0 cm standing water
9	6-20 cm standing water
10	> 20 cm standing water

The purpose of the Assemblages table is to quantitatively illustrate the environmental and floristic differences that occur between each assemblage. The table also portrays an idealized successional sequence that operates on the delta as elevation increases and habitats become dryer. The factors influencing succession are largely allogenic on the left side of the table, progressing to autogenic influences on the right side of the table.

5.4 Plant assemblages and allogenic succession

With few exceptions, the Aquatic, *Equisetum*, *Carex*, *Equisetum-Carex*, *Salix-Equisetum* and *Salix* assemblages occupy the youthful stages of landforms, those influenced greatly by the river and lake regime such as the alluvial sandbars along active distributaries. Succession influenced largely by environmental factors such as river water level is termed allogenic.

5.5 Aquatic assemblage

5.5.1 Distribution

The largest concentration of aquatic vegetation is in the cut off channels, where solar radiation is able to penetrate the relatively silt free water, thus promoting photosynthesis. The shallow portion of Great Slave Lake bordering the protected zone of the outer delta also supports aquatic vegetation. Dense growth of aquatic species does not occur along active channels because of scouring during flood stage and the high turbidity which prevents the penetration of sunlight.

5.5.2 Environment, vegetation analysis and successional status

The cut off channels with standing water are divided into four categories: 1) shallow ponded sloughs, 2) seasonally ponded sloughs, 3) open ponded sloughs and 4) deep ponded sloughs.

5.5.3 Shallow ponded sloughs

The most prominent type of cut off channel is the relatively shallow slough which contains standing water throughout the summer months. These sloughs support a dense littoral band of emergent vegetation which at times advances into the shallow portions of the slough. This emergent vegetation consists of a wide range of species, usually dominated by *Equisetum fluviatile*. The aquatic assemblage in these permanently ponded sloughs is limited by the shallowness of the water. Aquatic species present in Plot 18B-2 (Table 5.1), listed in decreasing order of significance include *Utricularia intermedia*, *Potamogeton vaginatus*, *P. perfoliatus* and *Hippurus vulgaris*. The dominant plant, *Utricularia intermedia*, was growing successfully but the other species exhibited poor vigour, probably because of the shallowness of the water (less than 15 cm on 1 August 1977).

5.5.4 Seasonally ponded sloughs

The second type of slough is similar to the first except that it dries up by mid summer, enabling a succession of emergent species. The number of seasonally ponded sloughs varies from year to year, depending upon flood level, amount of local snowmelt runoff, and climatic conditions influencing rainfall and evaporation.

The degree of encroachment of emergent species into the old channel bed is largely dependent upon the elevation of the bed above river level which in turn determines its height above the water table.

A great portion of these sloughs remain void of vegetation after they dry up in the latter summer probably in response to desiccation of the slough surface.

A slough studied on Transect 1 demonstrated the rapid encroachment of emergent vegetation. During the early part of the summer when standing water was present the vegetation along the banks of this slough resembled those described for the shallow ponded slough type. As the slough dried up (approximately 10 July 1977), *Equisetum fluviatile* invaded the slough bed and by 5 August it covered approximately 90% of the slough bed. Plot 1-4, Table 5.3 illustrates the species composition of the plot at this time. *Salix arbusculoides* is present in small patches throughout this plot, indicating that the seasonal aquatic cycle is not preventing succession toward a *Salix* assemblage.

5.5.5 Open ponded sloughs

These sloughs have been sealed off at one end preventing throughflow of river water (Section 4.4.2.2), but are open to a distributary at the other end and the vegetation is consequently influenced to a larger degree by the channel levels. Although throughflow does not occur, muddy water from the distributary can enter the channel every time there is a rise in channel levels.

Suspended sediment is therefore present in variable concentrations during the growing season which affects the composition of aquatic species in these sloughs. Channel C referred to in Section 4.4.2.4 is a good example of an open ponded slough. *Potamogeton gramineus* and *P. vaginatus* were present in small numbers, but *Utricularia* spp. and *Hippurus vulgaris*, species common in sloughs that are protected from sediment input during the summer, were absent because of the turbidity. For example secchi disc readings in Channel C on 2 August 1977 averaged only 20 cm.

5.5.6 Deep ponded sloughs

This type of slough appears to have been abandoned from the river for a long period of time as the levees which block them from active distributaries are well elevated and densely covered with terrestrial vegetation. Flood water seldom overtops the high banks, thus water in these sloughs remains clear. Secchi disc readings in one deep ponded slough (Willow Lake - Figure 4.20) were greater than 3 m on 26 June 1977.

The aquatic vegetation of Willow Lake is typical of deep ponded sloughs in the Slave Delta. The dominant vegetation is *Nuphar variegatum* which forms a wide band around the lake, covering approximately 20% of the surface of the lake. The littoral vegetation is dominated by *Equisetum fluviatile, Typha latifolia, Scirpus microcarpus* and *Sparganium eurycarpum*.

5.5.7 Aquatic vegetation in the protected zone of the outer delta

A factor which plays an important role in retarding the

development of aquatic vegetation in the basin of the protected zone of the outer delta is the continued high input of suspended sediment throughout the growing season. The turbidity of the water is emphasized by the shallowness of secchi disc readings which ranged from 3 cm on 30 May 1977 to 14 cm on 12 August 1977. This high concentration of suspended sediment is largely responsible for the rather limited growth of aquatic vegetation, as the sediment reduces the penetration of sunlight into the water and retards photosynthesis. Grainger similarly reports (1974) low inshore primary productivity at the mouth of the Mackenzie Delta because of river-contributed turbidity.

The turbidity throughout the summer in the basin is increased by the disturbance of the shallow topset beds by wave action. An interesting comparison can be made between this area and the protected interlevee depressions of the outer delta. Sediment entering these protected depressions settles out quickly enabling penetration of sunlight for photosynthesis. As a result, the growth of aquatic vegetation within these areas is much greater. The common aquatics found in the interlevee depressions are (in decreasing order of importance), *Lemna trisulca, Utricularia vulgaris, Lemna minor, Utricularia intermedia* and *Potamogeton* spp.

5.6 *Equisetum* assemblage

5.6.1 Distribution

Equisetum fluviatile has a wide geographical distribution (Hulten, 1974) and is an important pioneer species in northern deltas.

Reinelt *et al.* (1971) and Cordes and Strong (1976) emphasize the importance of this species in the Peace-Athabasca Delta; Gill (1971) notes its prominence along slipoff slopes and other alluviating environments in the Mackenzie Delta; Dirschl (1970) describes its distribution and ecology in the Saskatchewan River Delta and Dahlskog *et al.* (1972) report its significance and distribution on the Kvikkjokk Delta in Sweden.

The areal extent of *Equisetum* assemblages growing on the delta is shown in Figure 5.1. *Equisetum fluviatile* is the sole dominant in most of the exposed zone of the outer delta. In the mid delta, *Equisetum* species also have an important ecological role as they inhabit active point bar environments (Plate 17), large portions of sand bars (Plate 18) and abandoned channels (Plate 19). *Equisetum arvense* dominates the herb layer in many *Populus* stands and is an important species in the *Picea* and *Alnus* assemblages (Sections 5.17 and 5.14).

5.6.2 Environment

The *Equisetum* assemblage on the exposed, and in some portions of the protected outer Slave Delta provide a source of food for thousands of muskrats and migrating waterfowl on an annual basis. *Equisetum fluviatile* dominates the exposed zone of the outer delta occupying the large interlevee depressions of the cleavage bar island formations. Fine-grained sediment which is deposited in the interlevee depressions (Axelsson, 1967; Gill, 1971) increases the ability of the ground to accumulate nutrients by ion adsorption to

Plate 17: *Equisetum fluviatile* along a developing point bar at Four Ways. This site was sampled for weekly sediment accumulation (2 August 1977).

Plate 18: *Equisetum fluviatile* occupying a sand bar on the left bank of Steamboat Channel. Driftwood helps to stabilize and build up these features (27 June 1977).

Plate 19: *Equisetum fluviatile* inhabiting shallow ponded sloughs, channels cut off long ago from active distributaries (5 July 1977).

soil particles (Dahlskog, 1972) thus interlevee depressions of the outer delta provide a rich habitat for emergent plant species, notably *Equisetum fluviatile*. This plant is well adapted to the exposed outer delta as it tolerates semi-aquatic conditions, withstands wave action, flooding, high rates of sedimentation (Gill, 1971) and prolonged exposure to sunlight and wind.

The water in the centre of these interlevee depressions reaches approximately 1.2 m (August 1977 water level) and this depth of water discourages the invasion of willow species (which, if successful, would eliminate the shade-intolerant *Equisetum fluviatile*). The spatial distribution of plant development on a cleavage bar island is well represented in Figure 4.1 (Transect 12).

Contagious distribution and clonal development of *Equisetum fluviatile* along the shoreline of the protected zone of the outer delta is illustrated in Plate 20. Although clones of *Carex aquatilis* are present in this zone, *Equisetum fluviatile* dominates.

5.6.3 Vegetation analysis

As illustrated in Table 5.3, the average cover abundance of *Equisetum fluviatile* is 75%. The dominance of this species in the 21 plots sampled is emphasized as the next most important plant, *Carex rostrata* has an average cover abundance of less than 3%. The large number of sampled plots for *Equisetum* assemblages reflects the large areal extent of the assemblage (Figure 5.1) and the importance of *Equisetum fluviatile* as a pioneer species on the Slave Delta.

The *Equisetum* assemblages can be divided into 2 groups,

Table 5.3 *Equisetum* Assemblage

Stratum	Species	12B-3	12A-3	12A-4	8A-2	12A-5	12A-1	8B-1	8A-1	15-1	12B-1	13-2	9-3	5A-2A	17-3	11-3A	5A-2D	5A-2E	5A-2B	5C-1	1-4	10-3	Averages: Species Significance	Sociability	Vigour	Presence Value (percent)	Total cover (percent)
		Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour	Species Significance Sociability Vigour					
Shrub Layer	Percent total coverage	5	2	2	1	3	1	25	12	2	10	2		20						5	29	2					5
	Salix arbusculoides		1 1 3	1 1 2		1 1 2			2 1 2	1 1 2		2 3 3		3 1 2							5 2 2	1 2 2	1.9	1.4	2.2	43	
	Salix glauca	1 1 2	1 1 3	1 1 2	1 1 1	1 2 2		2 1 3	1 1 2		2 1 3	1 1 3		3 1 2							1 1 2	1 1 2	0.9	1.1	2.3	57	
	Salix interior	2 1 2					1 1 2	4 1 3	2 1 2	1 1 1	2 1 3												0.6	1.0	2.2	29	
	Alnus tenuifolia																			2 1 3	2 2 2		0.2	1.5	2.5	10	
	Salix lasiandra					1 1 2																	1.0	1.0	2.0	5	
	Cornus stolonifera																			1 2 2			0.1	2.0	2.0	5	
Herb Layer	Percent total coverage	100	100	100	100	100	85	100	85	55	100	100	100	95	100	100	90	100	100	80	100	100					97
	Equisetum fluviatile	8 4 4	8 4 4	9 5 4	9 5 4	9 5 4	7 3 4	9 5 4	7 3 4	7 3 4	[illegible]	7 3 4	8 4 4	6 3 3	8 4 4	8 4 4	8 4 4	7 3 4	9 5 4	4 1 3	8 4 4	8 4 4	7.7	3.8	3.9	100	
	Carex rostrata		1 1 2	1 1 3			1 1 2			2 1 3		2 1 2	3 1 3	4 2 3	1 1 2	2 1 3		4 2 3		2 2 3	3 2 3	4 3 3	1.4	1.5	2.7	62	
	Carex aquatilis		2 2 3	2 1 3			2 1 3			4 4 3	2 1 2	3 2 3	1 1 3	1 2 3	1 1 2			1 1 3		2 2 3		2 2 2	1.1	1.7	2.8	57	
	Equisetum palustre	2 1 2	2 1 3	1 1 3							1 1 1	2 1 2		4 3 3				3 1 3	2 1 3				0.8	1.3	2.5	38	
	Lemna trisulca	2 2 3	1 1 3	1 1 3	5 3 3	4 1 3		2 3 3															0.7	1.8	3.0	29	
	Sium Suave			1 1 3			1 1 3		1 1 3	1 1 3		1 1 3	2 1 3		4 1 3						2 1 3	2 1 3	0.7	1.0	3.0	43	
	Utricularia intermedia	3 2 3				5 1 3		5 3 3															0.6	2.0	3.0	14	
	Calamagrostis canadensis										2 1 2		2 1 2		2 1 2		1 1 3					5 3 3	0.6	1.4	2.4	24	
	Potentilla palustris	3 2 3	6 2 3																			2 1 2	0.5	1.7	2.7	14	
	Glyceria maxima grandis								2 1 3	1 1 2		2 1 3			2 2 2			4 1 3					0.5	1.2	2.6	24	
	Glyceria pauciflora												2 1 3			1 1 2						7 2 3	0.5	1.3	2.7	10	
	Utricularia minor																										
	Rorippa islandica																			4 1 3			0.4	1.0	2.0	10	
	Stellaria interior				3 3 3	3 1 3						1 1 3	1 1 3				4 1 3						0.3	1.0	3.0	14	
	Scirpus microcarpus															1 1 3							0.3	1.5	3.0	10	
	Cicuta mackenzieana																				4 2 3	2 2 2	0.3	1.7	2.1	14	
	Hippuris vulgaris															1 1 3				2 1 2		3 2 3	0.3	1.3	2.1	14	
	Lemna minor										2 1 2			5 2 3									0.3	1.5	2.5	10	
	Calamagrostis Langsdorffi			1 1 3			1 1 3		1 1 3	1 1 3		1 1 3				1 1 3							0.3	1.0	3.0	29	
	Potamogeton vaginatus				1 1 3	1 1 3	1 2 3	1 1 3													1 2 2	1 1 2	0.3	1.3	2.7	29	
	Stellaria calycantha	2 2 3						2 3 3															0.2	2.5	3.0	14	
	Ranunculus hyperboreas										2 1 2					2 1 3							0.2	1.0	2.5	10	
	Riccia fluitans			1 1 3		3 1 3																	0.2	1.0	3.0	10	
	Ricciocarpus natans																										
	Achillea sibirica																				2 1 3	2 2 2	0.2	1.5	2.5	10	
	Carex atherodes																				4 3 3	1 2 2	0.2	2.5	2.5	10	
	Carex media											1 1 3											0.1	1.0	3.0	5	
	Equisetum hiemale								1 1 2														0.1	1.0	2.0	5	
	Potamogeton gramineus									1 1 2													0.1	1.0	2.0	5	
	Epilobium angustifolium									1 2 2													0.1	2.0	2.0	5	
	Plantanthera hyperborea																					1 2 2	0.1	2.0	2.0	5	
	Equisetum arvense																					2 1 3	0.1	1.0	3.0	5	
	Scutellaria galericulata																			2 2 3			0.1	2.0	3.0	5	
	Stellaria crassifolia													3 2 3									0.1	2.0	3.0	5	
	Ranunculus multifidis															1 1 3							0.1	1.0	3.0	5	
	Potentilla norvegica															1 1 3							0.1	1.0	3.0	5	
	Sagittaria cuneata															1 1 3							0.1	1.0	3.0	5	
	Scirpus validus												2 1 3										0.1	1.0	3.0	5	
	Potentilla anserina														3 1 2								0.1	1.0	2.0	5	
	Mertensia paniculata										1 1 2												0.1	1.5	2.5	10	
	Petasites sagittatus									1 1 1													0.1	1.0	1.0	5	
	Alisma plantago aquatica									1 1 2													0.1	1.0	2.0	5	
	Ranunculus sceleratus									1 1 2													0.1	1.0	2.0	5	
	Eleocharis palustre									1 1 2					1 1 2	1 1 2							0.1	1.0	2.0	14	
																							0.1	1.0	3.0	5	

100 m

Plate 20 : Panchromatic aerial photograph (7 September 1977) illustrating the contagious distribution and clonal development of emergent vegetation in the protected zone of the outer delta (arrows).

Courtesy, Canadian Wildlife Service.

those sampled in the outer delta (plots 8A-1, 8A-2, 8B-1, 12A-1, 12A-3, 12A-4, 12A-5, 12B-1, 12B-3 and 13-2) and those sampled in the mid delta (plots 1-4, 5A-2A, 5A-2B, 5A-2D, 5A-2E, 5C-1, 9-3, 10-3, 11-3A and 17-3). The species composition of the assemblage in each zone appears to be a direct product of flooding history. The mid delta assemblages reflect a vegetation cover not necessarily exposed to the annual flooding which the outer delta assemblages experience. The significance of *Equisetum fluviatile* in the outer delta assemblages is somewhat greater than in the mid delta zone. In fact the only species having relatively significant success in the *Equisetum* assemblage of the outer delta either have an adventitious rooting system (ie., *Salix interior*) or are aquatic in nature (ie., *Utricularia vulgaris* and *Lemna trisulca*).

5.6.4 Successional trends

Succession from the *Equisetum* assemblage on the outer portion of the delta is directly related to the depth of water. Continued deposition on the cleavage bar islands will elevate the *Equisetum* beds and reduce water depths so that other successional species such as *Salix interior* can invade. In time the present *Equisetum* assemblage of the outer delta will occupy a drier environment and their species composition will approach that found in the *Equisetum* assemblage of the mid delta.

5.7 *Carex* assemblage

5.7.1 Distribution

The areal extent of relatively pure populations of *Carex*

species is illustrated in Figure 5.1. The largest concentrations are in the protected zone of the outer delta and on an island at the mouth of Steamboat Channel which is protected on its lake side by a wavebuilt shoal (Figure 4.27).

Smaller concentrations of *Carex* are found in thin strips along the littoral zones of most channels near Great Slave Lake, in small colonies on the distal portion of the exposed outer delta (usually on small shoals somewhat elevated above water level), and along some of the cut off channels in the mid delta and apex zones.

5.7.2 Environment

Carex assemblages inhabit a variety of environments on the Slave Delta. Although largely confined to the distal portions of the outer delta, there are colonies growing successfully in the mid delta and apex zones. Although the flooding frequency between these zones is significantly different, all the *Carex* assemblages sampled occupy environments which have greater than 40% soil moisture[1] (all samples taken in mid July 1977). The high moisture content of the soil sampled in the *Carex* assemblage in the apex zone (Plot 4-2, Table 5.1) is a product of topography and snowmelt. This plot is located in a perched channel defined here as a seasonally ponded slough (Section 5.5.4). During the early spring, melt water from the thawing snow collects in the slough which retains standing water until July.

[1]All soil samples in the assemblages were collected between 10 and 20 cm below the surface.

Although only one *Carex* assemblage was sampled in the seasonally ponded sloughs (reflecting the relative unimportance of this assemblage in the elevated portions of the mid delta and apex zones), other *Carex* assemblage sites observed occupied very similar habitats; all sites ponding snowmelt runoff in the spring.

The expanses of *Carex* assemblage in the protected zone of the outer delta are somewhat elevated above the water levels of the lake (July 1977) and consequently occupy sites which can be considered somewhat drier than those occupied by the *Equisetum* assemblage. The protected zone, as its name implies, is not susceptible to the constant wave action the exposed zone receives and consequently the protected zone has greater secchi disc readings - less turbidity. Generally speaking the *Carex* assemblage occupies drier habitat than the *Equisetum* assemblage. The hygrotope class (Table 5.2) average for the *Equisetum* assemblage sites on the outer delta is 10 while the average for the *Carex* assemblage sites is 8. These readings were taken in mid July 1977.

5.7.3 Vegetation analysis

Table 5.4 illustrates the floristics of the *Carex* assemblage. The plots sampled on the outer delta (8C-2, 12B-4 and 14-2) have shrub layers comprising not more than 35% of the total coverage. The assemblages sampled in the mid delta and apex zones have shrub layers occupying a smaller portion of the total area. This was also observed in *Carex* assemblages not sampled in the older areas of the delta as well.

Table 5.4 *Carex* ASSEMBLAGE

Sample Plot Number		8C-2				12B-4				14-2				6-1				4-2				Averages				
Stratum	Species	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Presence Value (percent)	Total cover (percent)
Shrub Layer	*Salix interior*	4	2	2	40	1	1	3	12	3	1	3	21	3	1	3	10				1	2.2	1.3	2.8	80	17
	Salix lasiandra	3	1	2		3	2	4		1	1	3										1.4	1.3	2.7	60	
	Salix arbusculoides	4	2	2		1	1	3		2	1	3										1.4	1.3	2.7	60	
	Salix glauca									2	1	3										0.4	1.0	1.0	20	
	Salix pseudomonticola																	1	1	2		0.2	1.0	2.0	20	
Herb Layer	*Carex aquatilis*	8	4	4	100	7	4	4	85	4	2	4	80	1	2	3	90	6	3	4	95	5.2	3.0	3.8	100	90
	Carex rostrata									2	2	2		5	2	4		7	3	4		2.8	2.3	3.3	60	
	Equisetum fluviatile					1	1	3		2	1	3		4	1	3						1.4	1.0	3.0	60	
	Typha latifolia	4	3	3		2	1	3														1.2	2.0	3.0	40	
	Scirpus microcarpus	2	3	3		2	1	2														0.8	2.0	2.5	40	
	Sparganium multipedunculatum	4	3	3																		0.8	3.0	3.0	20	
	Glyceria grandis													4	1	3						0.8	1.0	3.0	20	
	Beckmannia syzigachne													3	1	3						0.6	1.0	3.0	20	
	Carex media	2	1	2																		0.4	1.0	2.0	20	
	Equisetum palustre	1	1	2						1	1	3										0.4	1.0	2.0	20	
	Alisma plantego aquatica	1	1	2						1	1	3										0.4	1.0	2.0	20	
	Epilobium angustifolium									2	2	2										0.4	2.0	2.0	20	
	Scirpus validus					1	1	2														0.2	1.0	2.0	20	
	Sparganium eurycarpum					1	1	2														0.2	1.0	2.0	20	
	Potamogeton vaginatus	1	1	2																		0.2	1.0	2.0	20	
	Calamagrostis canadensis canadensis									1	1	3										0.2	1.0	3.0	20	
	Potentilla palustris									1	1	3										0.2	1.0	3.0	20	
	Sium suave									1	1	3										0.2	1.0	3.0	20	
	Stellaria longifolia									1	1	3										0.2	1.0	3.0	20	
	Aster sibiricus									1	1	3										0.2	1.0	3.0	20	
	Scutellaria galericulata									1	1	3										0.2	1.0	3.0	20	
	Rorippa islandica									1	1	3										0.2	1.0	3.0	20	
	Mertensia paniculata									1	1	3										0.2	1.0	3.0	20	
	Pyrola asarifolia									1	2	2										0.2	2.0	2.0	20	
	Achillea sibirica									1	1	3										0.2	1.0	3.0	20	
	Rumex occidentalis													1	1	3						0.2	1.0	3.0	20	

Dominance in this assemblage is generally shared by *Carex aquatilis* and *C. rostrata*, with *C. aquatilis* dominant in the outer delta zone; *C. rostrata* playing a prominent role in the older elevated sites. *Equisetum fluviatile* and *Typha latifolia* occurs in most *Carex* assemblages. *Typha latifolia* is present only in those colonies which have direct contact with the river or lake.

5.7.4 Successional trends

The outer delta plots all show indications of a successional trend toward a *Salix* assemblage, as *Salix interior*, *S. lasiandra* and *S. arbusculoides* are present in each plot. Cordes and Strong (1976) report that *Carex* communities in the Peace-Athabasca also succeed to *Salix* communities under natural conditions.

The assemblages observed in the mid delta and apex (including the sampled plot, 4-2) do not appear to be succeeding to any other assemblage.

5.8 *Equisetum-Carex* assemblage

5.8.1 Distribution

The *Equisetum-Carex* assemblage is not widespread on the delta and is found largely in the protected zone of the outer delta (Figure 5.1). Colonies of this assemblage exist in the exposed zone of the outer delta, but are of minor importance. The only 2 notable *Equisetum-Carex* assemblage sites in the mid delta zone were found on an open ponded slough (Plot 5A-2C, Table 5.5) and Rabbit Island (Figure 4.20).

5.8.2 Environment

The large expanse of *Equisetum-Carex* along the protected zone occupies an environment transitional between the large expanses of *Equisetum* along the exposed zone and the *Carex aquatilis* marshes occupying much of the Nagle Channel birds foot delta. This portion of the delta is protected enough (Section 4.4.1.3) to reduce the amount of sediment being deposited and the turbidity enabling *Carex aquatilis* to become established while at the same time providing a semi-aquatic environment for the successful growth of *Equisetum fluviatile*.

5.8.3 Vegetation analysis

This assemblage is dominated by *Equisetum fluviatile* as indicated in the floristic table of the *Equisetum-Carex* assemblage (Figure 5.5). For the 5 plots sampled, *Equisetum fluviatile* has an average cover abundance of 12%, *Carex aquatilis* and *C. rostrata* are subdominant with an average cover abundance of 10% and 5% respectively. Of the remaining 23 species in the herb layer, there appears to be little correlation between the environment and species composition.

5.8.4 Successional trends

Although sediment accumulation in the protected area of the outer delta is somewhat slower than those portions receiving discharge from larger distributaries, eventually the habitat presently supporting this assemblage in the protected zone will elevate to a position dry enough to enable *Salix* species to invade.

Table 5.5 *Equisetum-Carex* ASSEMBLAGE

Sample Plot Number		7-3				15-2				7-2				5A-2C				7-1				Averages				
Stratum	Species	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Presence Value (percent)	Total coverage (percent)
Shrub layer (< 3.0m)	*Salix interior*				15				3	3	1	3	11								3	.6	1.0	3.0	20	8
	Salix arbusculoides	2	1	3																		.4	1.0	3.0	20	
	Salix lasiandra					1	1	2										1	1	3		.4	1.0	2.5	40	
	Alnus tenuifolia					1	1	2										1	1	3		.4	1.0	2.5	40	
	Salix glauca	3	1	3		1	1	2		1	1	3						1	1	3		1.2	1.0	2.2	80	
Shrub layer (< 2.0m)	*Salix interior*					1	1	2	2													.2	1.0	2.0	20	2
	Salix arbusculoides					1	1	2														.2	1.0	2.0	20	
Herb layer	*Equisetum fluviatile*	4	2	4	43	4	2	3	85	4	2	3	43	6	2	4	94	3	1	3	47	4.2	1.8	3.4	100	62
	Carex aquatilis	3	2	3		4	2	3		4	2	3		4	2	3		2	2	3		3.4	2.0	3.0	100	
	Carex rostrata	2	2	3		2	2	3		1	2	3		3	1	3		2	2	3		2.0	1.8	3.0	100	
	Eleocharis palustris					1	1	3						6	1	3						1.4	1.0	3.0	40	
	Calamagrostis canadensis canadensis	2	1	3						1	1	3						3	1	3		1.2	1.0	3.0	60	
	Scirpus microcarpus					1	2	3										2	2	3		.6	2.0	3.0	40	
	Scutellaria galericulata					1	1	3										2	1	3		.6	1.0	3.0	40	
	Potentilla norvegica					1	1	2										2	1	3		.6	1.0	2.5	40	
	Petasites sagittatus					1	1	3		1	2	3										.4	1.5	3.0	40	
	Typha latifolia					1	1	3										1	1	3		.4	1.0	3.0	40	
	Carex media	1	1	3		1	1	3														.4	1.0	3.0	40	
	Eriophorum angustifolium	1	1	3		1	2	3														.4	1.5	3.0	40	
	Mertensia paniculata	1	1	3																		.2	1.0	3.0	20	
	Sium suave					1	1	3														.2	1.0	3.0	20	
	Beckmannia syzigachne					1	1	3														.2	1.0	3.0	20	
	Ranunculus hyperboreus					1	1	3														.2	1.0	3.0	20	
	Glyceria borealis					1	1	3														.2	1.0	3.0	20	
	Rorippa islandica					1	1	3														.2	1.0	3.0	20	
	Carex diandra					1	1	3														.2	1.0	3.0	20	
	Alisma plantego aquatica					1	1	3														.2	1.0	3.0	20	
	Sagittaria cuneata					1	1	3														.2	1.0	3.0	20	
	Scirpus validus					1	2	3														.2	2.0	3.0	20	
	Ranunculus Macounii																	1	1	3		.2	1.0	3.0	20	
	Calamagrostis canadensis Langsdorffii													1	1	3						.2	1.0	3.0	20	

5.9 *Salix-Equisetum* assemblage

5.9.1 Distribution

The range of habitat in which this assemblage occurs is very large (Figure 5.1). Plot 12A-2 (Table 5.1) is located along a cleavage bar levee in the exposed zone; plots 10-4 and 10-2 are located in the interlevee depression of a maturing cleavage bar island north of Little Fishery. Plots 4-4 and 4-7 are in the apex zone north of Nagle Channel. These two plots are undergoing secondary succession and will be discussed in Section 5.18.

5.9.2 Environment

Soil moisture, or depth of water appears to be the primary factor responsible for the establishment of this assemblage. Although only one site inhabiting a levee on a cleavage bar island was sampled (12A-2), several assemblages were noted along the outer delta. In all cases, the *Salix-Equisetum* were growing very successfully in 5 to 10 cm of water (August 1977 mean water level) overtopping the crests of levees. At depths of water greater than 10 cm, *Salix* species diminish in number; those present at greater depths exhibit poor vigour.

Portions of interlevee depressions of older cleavage bar formations in the mid delta zone have been elevated enough through sedimentation to provide habitat conducive to the establishment and success of *Salix-Equisetum* assemblage. The habitat provided by these interlevee depressions is in all observed cases dryer than the *Salix-Equisetum* habitat on the outer delta. The two sampled plots,

10-2 and 10-4 have less than 5 cm of standing water and 45% soil moisture respectively.

5.9.3 Vegetation analysis

The floristics of this assemblage is illustrated in Table 5.6. The *Salix-Equisetum* assemblage on the levees of the outer delta are largely dominated in the shrub layer by *Salix interior* (cover abundance of 20% in plot 12A-2) and in the herb layer by *Equisetum fluviatile* (30%). Other species of relative importance are *Equisetum palustre* (25%), *Scirpus microcarpus* (10%), *Salix glauca* (10%) and *Salix arbusculoides* (5%). Plot 12A-2 is typical of the vegetation composition and structure found on these levees.

The *Salix-Equisetum* assemblage found on the maturing cleavage bar islands of the mid delta are dominated in the shrub layer by *Salix arbusculoides*, with an average cover abundance of 55% (plots 10-2 and 10-4). The dominant role played by *Equisetum fluviatile* in the herb layer in the outer delta plots becomes less easily defined in these maturing cleavage bar interlevee depressions. Although *E. fluviatile* dominates the herb layer in plots 10-2 and 10-4 with an average cover abundance of 55%, *Potentilla palustris* (21%), *Beckmannia syzigachne* (10%), *Stellaria calycantha calycantha* (10%) and *Glyceria maxima grandis* (10%) contribute to a herb species composition that is noticeably different from the outer delta.

5.9.4 Successional trends

This assemblage is transitional between the *Equisetum* and *Salix* assemblages. As the willow canopy becomes more dense, the

Table 5.6

Salix-Equisetum ASSEMBLAGE

Sample Plot Number		12A-2				10-4				10-2				4-4				4-7				Averages				
Stratum	Species	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Presence Value (percent)	Total cover (percent)
Tree Layer (> 3 m)	*Picea glauca*													4	1	3	17	1	1	3	11	1.0	1.0	3.0	40	14
	Populus balsamifera																	3	1	3		0.6	1.0	3.0	20	
	Populus tremuloides													1	1	3						0.2	1.0	3.0	20	
Shrub Layer (> 2.0 m)	*Salix arbusculoides*	2	2	2	40	7	3	2	70	6	2	4	41				61	3	2	3	31	3.6	2.3	2.8	80	49.0
	Salix glauca	3	1	3		3	2	2		1	1	2						1	1	1		1.6	1.3	2.0	80	
	Salix interior	4	1	3														3	2	3		1.4	1.5	3.0	40	
	Salix planifolia													7	2	4						1.4	2.0	4.0	20	
	Alnus tenuifolia													3	1	3		3	2	3		1.2	1.5	3.0	60	
	Salix lasiandra	2	2	3																		0.4	2.0	3.0	20	
Shrub Layer (< 2.0 m)	*Salix interior*	4	1	3	25												8				25	0.8	1.0	3.0	20	19.0
	Ribes hudsonianum													2	1	3		2	1	3		0.8	1.0	3.0	40	
	Rosa acicularis																	4	3	3		0.8	3.0	3.0	20	
	Salix glauca	2	1	3																		0.4	1.0	3.0	20	
	Cornus stolonifera													1	2	3						0.2	2.0	3.0	20	
	Rosa woodsii													1	2	3						0.2	2.0	3.0	20	
	Ribes oxyacanthoides													1	1	3						0.2	1.0	3.0	20	
Herb Layer	*Equisetum fluvatile*	6	3	4	95	6	2	4	90	7	3	4	100				90				100	3.8	1.6	4.0	60	94.0
	Beckmannia syzigachne					2	2	2		5	1	3						3	2	3		2.0	1.7	1.6	60	
	Potentilla palustris					4	3	3		5	3	3										1.8	3.0	3.0	40	
	Calamagrostis canadensis canadensis					4	2	2						3	1	3		2	1	2		1.8	1.3	2.3	60	
	Stellaria calycantha calycantha					2	2	3		4	2	3		1	1	3						1.4	1.7	3.0	60	
	Glyceria maxima grandis					3	2	2		3	2	2										1.2	2.0	2.0	40	
	Equisetum palustre	5	1	3																		1.0	1.0	3.0	20	
	Carex rostrata					2	2	3										2	2	3		0.8	2.0	3.0	40	
	Pedicularis labradorica													4	1	3						0.8	1.0	3.0	20	
	Epilobium angustifolium													1	1	1		3	1	3		0.8	1.0	2.0	40	
	Scirpus microcarpus	3	2	3																		0.6	2.0	3.0	20	
	Equisetum arvense													6	2	4		7	3	4		2.6	2.5	4.0	40	
	Utricularia intermedia	3	3	3																		0.6	3.0	3.0	20	
	Sium suave	1	1	3						2	1	3										0.6	1.0	3.0	40	
	Carex diandra					1	1	2		3	2	2										0.6	1.5	2.0	40	
	Stellaria calycantha interior					1	1	2		2	2	2										0.6	1.5	2.0	40	
	Fragaria virginiana													3	2	3						0.6	2.0	3.0	20	
	Petasites sagittatus													2	1	3		1	1	2		0.6	1.0	2.5	40	
	Ranunculus sceleratus																	3	1	3		0.6	1.0	3.0	20	
	Rubus arcticus acaulis																	2	1	3		0.4	1.0	3.0	20	
	Rubus pubescens																	2	2	2		0.4	2.0	2.0	20	
	Cinna latifolia																	2	1	3		0.4	1.0	3.0	20	
	Eleocharis palustris									2	2	2										0.4	2.0	2.0	20	
	Platanthera hyperborea					1	1	2						1	1	3						0.4	1.0	2.5	40	
	Carex aquatilis					1	1	2														0.2	1.0	2.0	20	
	Parnassia palustris													1	1	2						0.2	1.0	2.0	20	
	Achillea sibirica													1	1	1						0.2	1.0	1.0	20	
	Moneses uniflora																	1	2	3		0.2	2.0	3.0	20	
	Pyrola minor																	1	1	2		0.2	1.0	2.0	20	
	Linnaeas borealis																	1	1	2		0.2	1.0	2.0	20	
	Cornus canadensis																	1	1	3		0.2	1.0	3.0	20	
	Cicuta mackenzieana	1	1	3																		0.2	1.0	3.0	20	
	Typha latifolia	1	1	3																		0.2	1.0	3.0	20	

shade intolerant subdominant *Equisetum fluviatile* will die out. In several levees along the outer delta, *Equisetum palustre* may replace *Equisetum fluviatile* as the subdominant herb, as it is able to tolerate shade to a greater extent.

The successional trend in the maturing interlevee depressions appears to be somewhat different. The dominant *Salix arbusculoides* is growing in small clumps enabling *Equisetum fluviatile* and other herbs to grow successfully in the open spaces. Although there are no *Alnus tenuifolia* present in the sampled assemblage, the species is beginning to invade the perimeters of these elevated interlevee depressions indicating that *Alnus tenuifolia* may play a role in the succession of this assemblage to *Salix-Alnus* or *Alnus-Salix* assemblage.

5.10 *Salix* assemblage

5.10.1 Distribution

The *Salix* assemblage is found mainly along elevated levees in the distal portions of the delta (Figure 5.1). Plots 13-1 and 8-1 (Table 5.1) occupy such habitat. In the mid delta *Salix* assemblage occupies portions of some elevated interlevee depressions, elevated portions of point bars, and sandbars (such as Plot 17-1 located on the left bank of Steamboat Channel). *Salix* assemblages are found only rarely in the apex zone (Plot 4-3).

5.10.2 Environment

Due to greater elevation than the *Equisetum, Carex, Equisetum-Carex* or *Salix-Equisetum* habitat, the *Salix* habitat

exhibits dryer soils (Table 5.1). On the average the sampled sites in the *Salix* stands have 35% soil moisture content. The exception to the relative dryness of this assemblage is plot 8-1 which had, at date of sampling (13 July 1977) 5 cm of standing water.

5.10.3 Vegetation analysis

Table 5.7 illustrates the floristics of this assemblage. The plots sampled were inhabited by only 5 species of *Salix*; in decreasing order of importance and with corresponding average cover abundance values they are *Salix interior* (35%), S. arbusculoides (11%), S. glauca (5%), *S. planifolia* (1%) and *S. lasiandra* (1%). According to Moss (1974) and Rowe (1972) many more species of *Salix* should inhabit this area of the boreal forest. Gill (1971) notes however that the environmental constraints of northern alluvial habitats restrict the development of the normally tolerant Salicaceae, to the degree that he found only 6 species of *Salix* in the Mackenzie Delta. Cordes and Strong (1976) report 9 species of *Salix* on the Peace-Athabasca Delta. Six species of *Salix* were found on the Slave Delta, *Salix pseudomonticola* the only species not included in the *Salix* assemblages sampled.

The composition of the herb layer varies to some extent in each plot. The herb layer reflects a contagious pattern; there is no correlation between soil moisture and plant composition. *Carex aquatilis*, *Calamagrostis canadensis canadensis* and *Carex rostrata* occurred abundantly in three of the four plots with respective average cover abundance of 10%, 4% and 2%.

Table 5.7 *Salix* ASSEMBLAGE

Sample Plot Number		4-3				17-1				13-1				8-1				Averages				
Stratum	Species	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Presence Value (percent)	Total coverage (percent)
Tree layer (> 3m)	*Populus tremuloides*	1	1	3	2													.25	1.0	3.0	25	1
	Picea glauca	1	1	2														.25	1.0	2.0	25	
Shrub layer	*Salix interior*	1	2	1	98	6	1	3	81	7	2	4	91	7	2	4	100	5.3	1.8	3.0	100	92
	Salix arbusculoides	2	2	2		4	1	3		5	2	3		3	2	1		3.5	1.8	2.3	100	
	Salix planifolia	8	4	4														2.0	4.0	4.0	25	
	Salix glauca					1	1	2		2	2	3		4	2	2		1.8	1.7	2.3	75	
	Salix lasiandra									2	2	3		3	2	2		1.3	2.0	2.5	50	
	Alnus tenuifolia	1	1	2		2	1	3		1	1	2						1.3	1.0	2.3	75	
	Cornus stolonifera	1	1	2														.3	1.0	2.0	25	
	Ribes hudsonianum	1	1	3														.3	1.0	3.0	25	
Herb layer	*Carex aquatilis*	2	2	3	73				41	3	2	3	42	8	4	4	100	3.3	2.7	3.3	75	64
	Calamagrostis canadensis canadensis	5	1	3		3	1	3		1	2	3						2.3	1.3	3.0	75	
	Equisetum arvense	5	3	3						1	1	2						1.3	2.0	2.5	50	
	Carex rostrata	1	2	3						2	2	3		2	1	3		1.3	1.7	3.0	75	
	Equisetum palustre					2	1	3		3	1	3						1.3	1.0	3.0	50	
	Equisetum fluviatile					4	1	3		1	1	3						1.3	1.0	2.5	50	
	Scirpus microcarpus					2	1	3		1	2	3						.8	1.5	3.0	50	
	Petasites sagittatus	2	2	3														.5	2.0	3.0	25	
	Potentilla anserina					1	1	2		1	1	2						.5	1.0	2.0	50	
	Calamagrostis canadensis Langsdorffii													2	2	2		.5	2.0	2.0	25	
	Eleocharis palustris													1	2	1		.3	2.0	1.0	25	
	Juncus alpinus													1	2	1		.3	2.0	1.0	25	
	Glyceria pauciflora													1	2	1		.3	2.0	1.0	25	
	Glyceria grandis													1	2	1		.3	2.0	1.0	25	
	Pyrola secunda secunda					1	1	2										.3	1.0	2.0	25	
	Typha latifolia					1	1	2										.3	1.0	2.0	25	
	Sium suave					1	1	2										.3	1.0	2.0	25	
	Platanthera obtusa									1	1	2						.3	1.0	2.0	25	
	Platanthera hyperborea									1	1	3						.3	1.0	3.0	25	
	Stellaria calycantha calycantha	1	1	3														.3	1.0	3.0	25	
	Fragaria virginiana	1	1	3														.3	1.0	3.0	25	

5.10.4 Successional trends

Although *Salix* species dominate the shrub layer in this assemblage, *Alnus tenuifolia* was recorded in small amounts (plots 4-3, 17-1 and 13-1), indicating the common successional trend from a *Salix* to a *Salix-Alnus* assemblage. A similar successional sequence takes place in the Mackenzie Delta (Gill, 1975a). In the Peace-Athabasca Delta however, the *Salix* community usually succeeds to a *Populus* community (Cordes and Strong, 1976).

5.11 Plant assemblages and autogenic succession

The assemblages discussed hereafter mainly occupy the older delta landforms such as the islands of the mid delta and apex zone. Succession operating within the *Salix-Alnus*, *Alnus-Salix*, *Alnus*, *Populus*, Decadent *Populus* and *Picea* assemblages is to a large degree autogenic. The *Salix-Alnus* assemblage is transitional between the allogenically and autogenically influenced plant succession. Autogenic succession is that mainly influenced by the vegetation structure and composition.

5.12 *Salix-Alnus* assemblage

5.12.1 Distribution

The areal extent of the *Salix-Alnus* assemblage is illustrated in Figure 5.1. Distribution is largely limited to the upstream levees of cleavage bar islands in the outer delta (Plots 12B-2 and 14-1) and portions of the mid delta zone. In the mid delta, the assemblage sites sampled occurred on a developing sand bar (Plot

17-2), on the crest of a meander scroll of a point bar (Plot 11-1) and on an abandoned shoreline along Transect 2 (Plot 2-3).

There are very few *Salix-Alnus* assemblages in the apex zone.

5.12.2 Environment

The *Salix-Alnus* sampled in the outer delta occupy substantially different habitat than those sampled in the mid delta. The major difference is the amount of soil moisture found in the sampled sites. The plots in the outer delta have between 5 and 10 cm of standing water while the mid delta plots have between 25 and 29% soil moisture. The primary reason why *Salix-Alnus* are termed the transitional assemblage between allogenic and autogenic succession is because this assemblage can maintain its assemblage status within a great range of environment.

5.12.3 Vegetation analysis

Table 5.8 illustrates the floristics of the *Salix-Alnus* assemblage. The shrub layers are dominated by *Salix* species. *Salix interior* has an average cover abundance for the 5 plots sampled of 7%, *S. lasiandra* and *S. arbusculoides* have an average cover abundance of 5% and *Alnus tenuifolia*, the subdominant shrub has an average cover abundance of 10%.

The herb layer reflects a contagious pattern similar to that of the *Salix* assemblage. There is no correlation between soil moisture and plant composition, although Plot 14-1 is flooded annually, which may explain the large number of species found at that

Table 5.8 *Salix–Alnus* ASSEMBLAGE

Sample Plot Number		14-1				2-3				17-2				12B-2				11-1				Averages				
Stratum	Species	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Presence Value (percent)	Total cover (percent)
Shrub Layer (> 2.0 m)	*Alnus tenuifolia*	5	1	3	95	7	2	3	100	6	2	3	100	6	2	3	100	5	2	3	90	5.8	1.8	3.0	100	98
	Salix lasiandra	4	1	3		7	3	3		5	2	4		4	2	3		3	1	3		4.6	1.8	3.2	100	
	Salix interior	5	1	3		3	2	2		4	2	3		4	2	3		5	1	3		4.2	1.6	2.8	100	
	Salix arbusculoides	4	1	3		2	2	3		5	2	3		4	2	3		4	1	3		3.8	1.6	3.0	100	
	Salix glauca									1	2	3										0.2	2.0	3.0	20	
Shrub Layer (< 2.0 m)	*Salix interior*	3	1	3	20	6	1	4	52	4	1	3	40	4	2	3	50					3.4	1.3	3.3	80	32
	Salix arbusculoides	2	1	3		1	1	3		4	1	2		4	2	3						2.2	1.3	2.8	80	
	Salix lasiandra	2	1	2		1	1	2		2	2	2		3	2	2						1.6	1.5	2.0	80	
	Salix glauca									2	2	2										0.4	2.0	2.0	20	
	Cornus stolonifera					6	2	4														1.2	2.0	4.0	20	
Herb Layer	*Equisetum fluviatile*	5	1	4	80				80	7	3	4	100				55	3	1	3	36	3.0	1.7	3.7	80	70.2
	Equisetum palustre	2	1	3		2	1	3		5	1	3		3	1	2						2.4	0.8	2.8	80	
	Calamagrostis canadensis canadensis	2	2	3		5	1	3										2	1	3		1.8	1.3	3.0	60	
	Scirpus microcarpus	3	2	3						3	1	2						2	2	3		1.6	1.7	2.7	60	
	Equisetum arvense					5	1	3														1.0	1.0	3.0	20	
	Sium suave	1	1	3										2	1	3						0.6	1.0	3.0	20	
	Carex rostrata									3	1	3										0.6	1.0	3.0	80	
	Sparganium eurycarpum	2	2	3																		0.4	2.0	3.0	20	
	Typha latifolia	2	1	3																		0.4	1.0	3.0	20	
	Platanthera obtusata					1	1	3										1	2	3		0.4	1.5	3.0	40	
	Cicuta mackenzieana													2	1	3						0.4	1.0	3.0	20	
	Pyrola secunda secunda													1	1	1						0.2	1.0	1.0	20	
	Rorippa islandica					1	1	2														0.2	1.0	2.0	20	
	Castilleja miniata					1	1	2														0.2	1.0	2.0	20	
	Galium triflorum					1	1	2														0.2	1.0	2.0	20	
	Moneses uniflora					1	3	3														0.2	3.0	3.0	20	
	Petasites sagittatus	1	2	3																		0.2	2.0	3.0	20	
	Glyceria grandis	1	1	3																		0.2	1.0	3.0	20	
	Stellaria longifolia	1	1	3																		0.2	1.0	3.0	20	
	Potentilla palustris	1	1	3																		0.2	1.0	3.0	20	
	Platanthera hyperborea	1	2	3																		0.2	2.0	3.0	20	
	Petasites palmatus	1	2	3																		0.2	2.0	3.0	20	
	Eleocharis palustris	1	2	3																		0.2	2.0	3.0	20	

site.

Common members of the herb layer are *Equisetum fluviatile* (average cover abundance of 10%), *E. palustre* (7%) and *Scirpus microcarpus* (4%). The presence of shade intolerant *Equisetum fluviatile* (cover abundance of 65%) in Plot 17-2 is related to the spacing of the shrub canopy. They are spaced in groups which allows the *Equisetum* to grow in the open areas. In plots 14-1 and 11-1, the canopy has greater crown cover, thus *Equisetum fluviatile* has less cover abundance. As the canopy becomes more dense, it shades the ground and the shade-intolerant *Equisetum fluviatile* is succeeded by shade-tolerant species.

5.12.4 Successional trends

The *Salix-Alnus* assemblage succeeds to an *Alnus* assemblage as shown by the significant presence and vigorous growth of *Alnus tenuifolia* in each plot. In the Mackenzie Delta, *Salix-Alnus* communities usually succeed to the climax *Picea* stage (Gill, 1975a) without intermediate successional stages. In the Peace-Athabasca Delta, Dirschl *et al.* (1974) report that *Salix-Alnus* succeeds to a *Populus* community. The transition differs on the Slave Delta. Usually the *Salix-Alnus* assemblage succeeds to an *Alnus-Salix* or an *Alnus* stage before progression to the *Populus* and *Picea* assemblages.

5.13 *Alnus-Salix* assemblage

5.13.1 Distribution

Fifteen *Alnus-Salix* plots were sampled on the delta. The large number of sample plots reflects the broad areal extent of the

Alnus-Salix assemblage (Figure 5.1).

Along the outer delta, *Alnus-Salix* are found only on the most elevated upstream portions of cleavage bar islands. This assemblage is widespread in the mid delta, commonly occupying the backslopes of active levees (Table 5.1; Plots 1-2, 9-2, 2-2, 1-3, 3-3) and in great abundance along levees of small distributaries to the east of Resdelta Channel (Plots JR-1, JR-2, 10-1). Levees along abandoned channels (Plot 18A-1), abandoned point bars (11-2A), back-swamps behind cut-bank levees (5B-1, 5B-2) and upstream portions of islands (3-1, 3-2, 3-4) are among the varied habitat *Alnus-Salix* occupy in the mid delta zone. The *Alnus-Salix* assemblage does not play a large role in the vegetation composition of the apex zone.

5.13.2 Environment

The average soil moisture content of the *Alnus-Salix* assemblage is 25%, considerably dryer than the *Salix-Alnus* assemblages which normally occupy the successional stage prior to *Alnus-Salix*. This soil moisture difference reflects the more elevated habitat which *Salix-Alnus* occupy. The plots sampled along the backslopes of active levees are higher in soil moisture and have cooler soil temperatures (Figure 5.2) than the crests of the levees. These are not restricting environmental factors however, as evidenced by the highly variable soil moisture and temperatures within the *Alnus-Salix* assemblage located on the upstream end of Mouse Island (Figure 5.3).

The *Alnus-Salix* sites to the east of Resdelta Channel occupy levees along stable, open ponded sloughs where erosional change

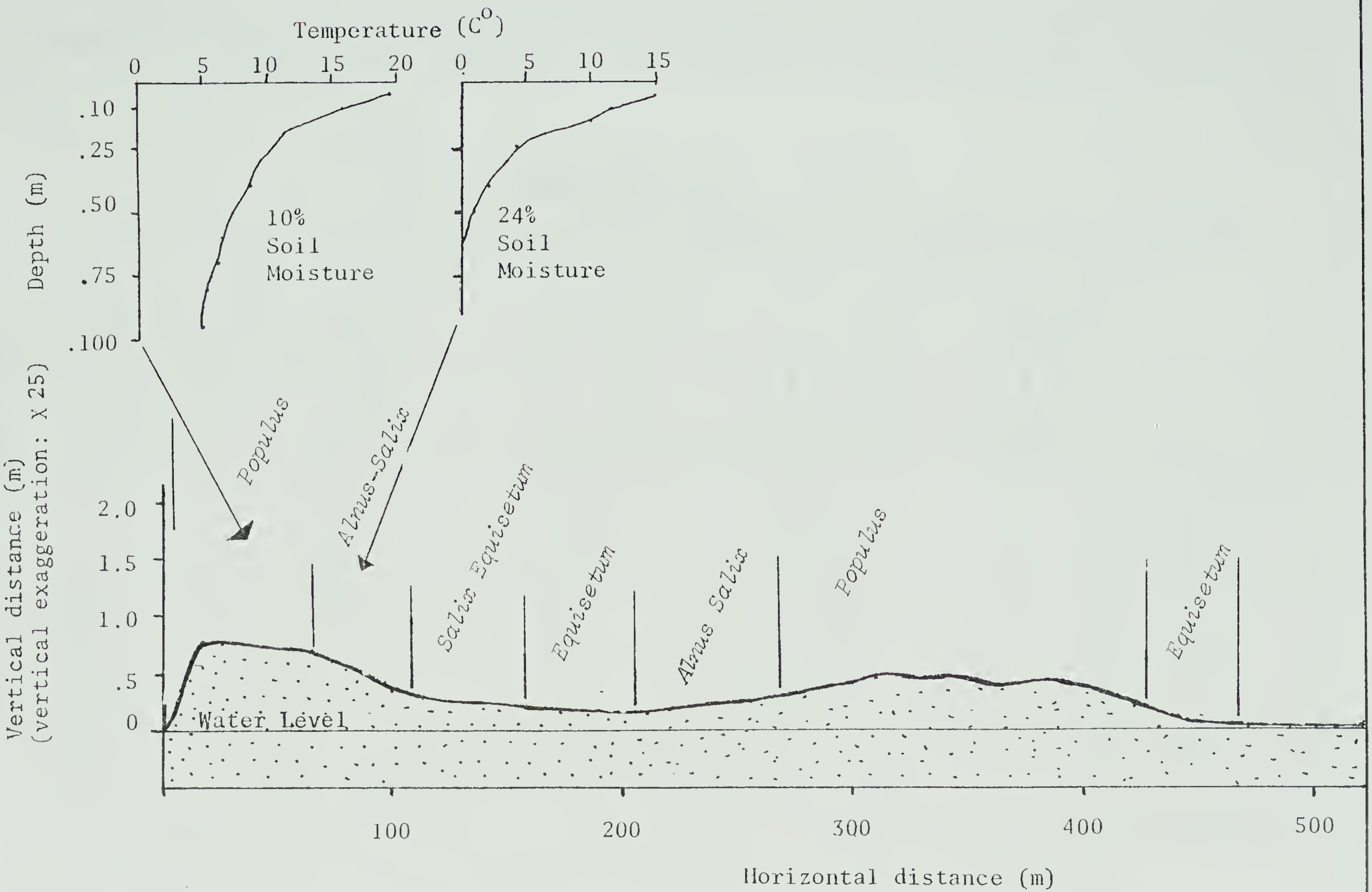
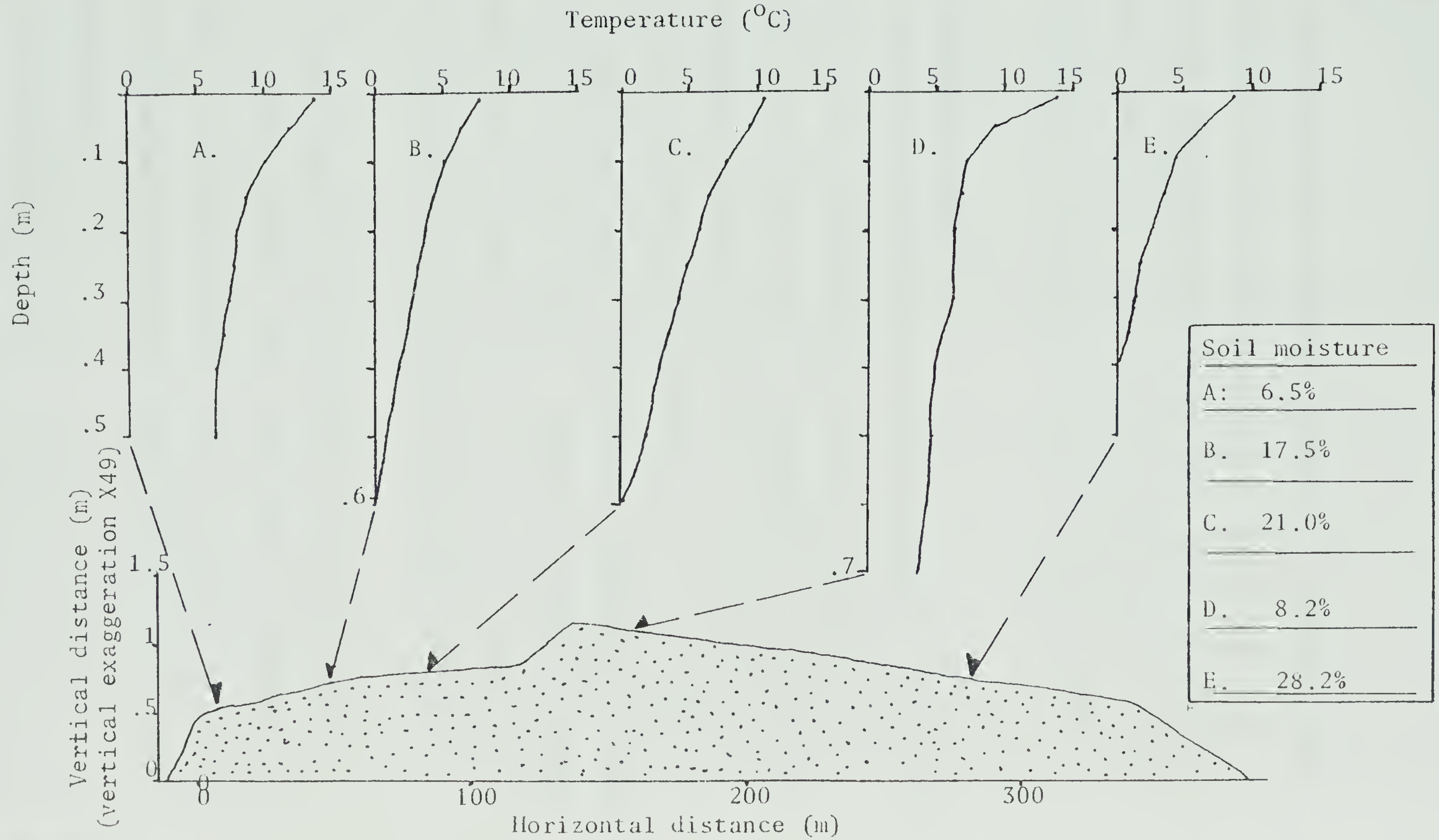


Figure 5.2: Transect 9, Plant assemblages (sampled 25 July 1977)
All soil samples taken between 10 and 20 cm below the ground surface.

Figure 5.3 : Transect 3, soil temperature profiles and soil moisture, (sampled 11 June, 1977). Soil moisture samples taken approximately 20 cm below the ground surface.



is infrequent.

The *Alnus-Salix* assemblage occupying a backswamp along Transect 5B (Figure 5.4) is actually growing on large hummocks elevated above the standing water (Figure 5.5). Soil moisture in the hummocks averaged 32.2%, emphasizing the effectiveness of the landform in providing a relatively dry site for vigorous plant growth.

5.13.3 Vegetation analysis

The floristics of the *Alnus-Salix* assemblage are illustrated in Table 5.9. This assemblage has a species composition that is distinct from the *Salix-Alnus* and *Alnus* assemblages. The difference in species composition between *Salix-Alnus* and *Alnus-Salix* is due to the soil moisture difference discussed in Section 5.13.2. The reason for the difference noted between species composition of *Alnus-Salix* and *Alnus* is not that apparent. Although the *Alnus* assemblage usually occupies sites of greater elevation than those inhabited by *Alnus-Salix*, soil moisture values between assemblages is barely discernable.

Alnus tenuifolia is the dominant tall shrub with an average cover abundance of 75%. *Cornus stolonifera* is dominant in the low shrub layer with an average cover abundance of 45%. The herb layer is dominated by *Equisetum arvense* which has an average cover abundance of 45%.

Although the plots sampled occupy quite different habitats, they have a similar species composition. Even the herb layer shows a

Table 5.9

Alnus Salix Assemblage

Stratum	Species	3-1				3-3				11-2A				3-2				1-2			
		Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage
Tree Layer (> 3 m)	*Populus balsamifera*									3	1	3	10								
Shrub Layer (> 2 m)	*Alnus tenuifolia*	5	2	2	50	8	2	4	100	6	2	4	70	7	2	4	100	7	4	4	80
	Salix arbusculoides					5	2	3										3	1	2	
	Salix lasiandra					3	2	3													
	Salix pseudomonticola					1	2	3		4	1	3									
	Salix planifolia	4	2	3										6	2	3.					
	Salix interior	2	1	3										1	1	2					
Shrub Layer (< 2 m)	*Cornus stolonifera*					5	2	3	35	7	2	3	75	1	1	2	1				40
	Rubus melanolasius					1	1	3		2	1	3						4	2	3	
	Ribes hudsonianum									2	1	3						3	1	3	
	Rosa acicularis																				
	Ribes oxyacanthoides									2	1	3						2	1	3	
	Salix arbusculoides					2	2	2													
	Rubus arcticus acaulis																				
	Salix pseudomonticola																				
	Ribes lacustre																				
	Rosa woodsii									1	1	3						2	1	3	
	Salix lasiandra					1	2	2													
Herb Layer	*Equisetum arvense*				3	8	4	4	100	4	1	3	31	1	1	3	3	2	1	2	30
	Calamagrostis canadensis canadensis									2	1	3									
	Equisetum fluviatile	1	1	3		2	1	3													
	Epilobium angustifolium									2	1	3						3	1	3	
	Castilleja miniata																	2	1	2	
	Carex rostrata																				
	Glyceria pauciflora																				
	Stellaria calycantha calycantha					1	1	3													
	Calamagrostis canadensis Langedorffi																				
	Potentilla palustris																	2	1	3	
	Achillea sibirica																	2	1	2	
	Pyrola asarifolia																	2	1	3	
	Heracleum lanatum									1	2	3									
	Petasites sagittatus																				
	Pyrola secunda obtusata									2	1	3									
	Scutellaria galericulata																				
	Sium Suave																				
	Fragaria virginiana																				
	Stellaria longifolia																				
	Pyrola secunda secunda																				
	Sagittaria cuneata																				
	Equisetum palustre													1	1	3					
	Mertensia paniculata					1	1	2													
	Cinna latifolia					1	1	1													
	Dryas integrifolia integrifolia					1	1	3													
	Eleocharis palustris	1	1	3										1	1	2					

Stratum	Species	18A-1				JR-2				9-1				JR-1				3-4			
		Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage
Tree Layer (> 3 m)	*Populus balsamifera*					4	1	3	20	2	1	3	5	3	1	3	10				
Shrub Layer (> 2 m)	*Alnus tenuifolia*	7	2	3	100	7	2	4	100	9	4	4	100	7	2	4	100	7	2	4	100
	Salix arbusculoides	4	3	3		6	2	3		3	2	3		6	2	4		5	2	3	
	Salix lasiandra	5	3	4										3	2	3					
	Salix pseudomonticola									1	2	2						4	2	3	
	Salix planifolia																				
	Salix interior																				
Shrub Layer (< 2 m)	*Cornus stolonifera*	4	2	3	71	7	2	3	92	8	2	4	100	7	2	3	90	6	2	3	55
	Rubus melanolasius					6	2	3		2	1	3		6	2	3					
	Ribes hudsonianum	6	2	3		1'	2	2						1	2	2					
	Rosa acicularis	1	2	3		1	1	2		4	1	3		1	1	2		2	2	3	
	Ribes oxyacanthoides																	1	2	2	
	Salix arbusculoides																				
	Rubus arcticus acaulis																				
	Salix pseudomonticola																				
	Ribes lacustre									2	1	3									
	Rosa woodsii																				
	Salix lasiandra																				
Herb Layer	*Equisetum arvense*	8	4	4	100	8	4	4	100	5	1	3	32	8	4	4	100	8	4	4	100
	Calamagrostis canadensis canadensis					4	2	3		2	1	3		7	2	3		7	2	3	
	Equisetum fluviatile	4	1	3		3	1	3		1	1	3									
	Epilobium angustifolium					2	1	2						4	1	2					
	Castilleja miniata																				
	Carex rostrata					3	2	3		1	1	3									
	Glyceria pauciflora	4	2	3																	
	Stellaria calycantha calycantha																	1	1	3	
	Calamagrostis canadensis Langedorffi					3	2	3													
	Potentilla palustris																				
	Achillea sibirica																				
	Pyrola asarifolia					1	1	2													
	Heracleum lanatum					1	2	2													
	Petasites sagittatus																	2	1	3	
	Pyrola secunda obtusata																				
	Scutellaria galericulata					2	2	3													
	Sium Suave					1	2	2						1	2	2					
	Fragaria virginiana					2	1	3													
	Stellaria longifolia					2	2	2													
	Pyrola secunda secunda					2	2	2													
	Sagittaria cuneata					1	2	2													
	Equisetum palustre																				
	Mertensia paniculata																				
	Cinna latifolia																				
	Dryas integrifolia integrifolia																				
	Eleocharis palustris																				

Stratum	Species	58-1				10-2				2-2				1-3				5B-2				Averages				
		Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Presence Value (percent)	Total Cover (percent)
Tree Layer (> 3 m)	*Populus balsamifera*	2	1	3	5	2	1	3	2													1.1	1.0	3.0	40	8
Shrub Layer (> 2 m)	*Alnus tenuifolia*	6	2	4	85	8	2	4	100	9	3	4	100	8	2	4	100	8	2	4	100	7.3	2.2	3.7	100	93
	Salix arbusculoides	3	1	2		2	1	3		7	2	4		6	2	3		7	2	4		3.8	1.8	3.1	80	
	Salix lasiandra	5	1	2		6	2	3														1.5	2.0	3.0	33	
	Salix pseudomonticola																	3	2	3		0.9	2.3	2.6	33	
	Salix planifolia																					0.7	2.0	3.0	13	
	Salix interior																					0.2	1.0	2.5	13	
Shrub Layer (< 2 m)	*Cornus stolonifera*	9	2	4	100	7	3	4	93	5	2	3	57	2	1	3	27	4	2	3	25	4.8	1.9	3.2	87	57
	Rubus melanolasius	1	2	3		3	3	3		1	1	2										1.7	1.7	2.9	60	
	Ribes hudsonianum					3	2	3		2	2	3										1.2	1.7	2.7	45	
	Rosa acicularis	1	1	2		3	1	3		1	1	3		1	1	2						1.0	1.2	2.6	60	
	Ribes oxyacanthoides									4	2	3		1	1	2						0.7	1.4	2.6	33	
	Salix arbusculoides	3	1	2														2	1	2		0.5	1.3	2.0	20	
	Rubus arcticus acaulis																	1	1	1		0.1	1.0	1.0	6	
	Salix pseudomonticola	2	3	3																		0.1	3.0	3.0	6	
	Ribes lacustre																					0.1	1.0	3.0	6	
	Rosa woodsii																					0.2	1.0	3.0	13	
	Salix lasiandra																					0.1	2.0	2.0	6	
Herb Layer	*Equisetum arvense*	8	4	4	100	8	4	4	100	6	2	4	52	5	1	3	75	7	2	4	100	6.14	2.6	3.2	93	68
	Calamagrostis canadensis canadensis	2	1	3						3	2	3		5	1	4		3	1	3		2.30	1.4	3.1	60	
	Equisetum fluviatile	2	1	3										1	1	2		4	1	3		1.20	1.0	2.9	53	
	Epilobium angustifolium					2	1	3														0.90	1.0	2.6	33	
	Castilleja miniata									1	3	2		1	1	2						0.70	1.7	2.0	20	
	Carex rostrata																					0.27	1.5	3.0	13	
	Glyceria pauciflora																					0.30	2.0	3.0	6	
	Stellaria calycantha calycantha																	2	1	3		0.30	1.0	3.0	20	
						2	1	3														0.20	1.0	3.0	6	
	Calamagrostis canadensis Langedorffi																					0.20	2.0	3.0	6	
	Potentilla palustris													1	1	2						0.20	1.0	2.5	13	
	Achillea sibirica									1	3	2										0.20	2.0	2.0	13	
	Pyrola asarifolia																					0.20	1.0	2.5	13	
	Heracleum lanatum																	1	3	3		0.20	2.3	2.7	20	
	Petasites sagittatus													1	1	2						0.2	1.0	2.5	13	
																						0.2	2.0	3.0	6	
	Pyrola secunda obtusata																					0.1	1.0	3.0	6	
	Scutellaria galericulata																					0.1	2.0	3.0	6	
																						0.10	2.0	2.0	6	
	Sium Suave																					0.10	2.0	2.0	6	
	Fragaria virginiana																					0.10	2.0	2.0	6	
	Stellaria longifolia																					0.10	2.0	2.0	6	
	Pyrola secunda secunda																					0.13	2.0	2.0	6	
	Sagittaria cuneata													1	2	2						0.10	2.0	2.0	13	
	Equisetum palustre																					0.10	1.0	3.0	6	
	Mertensia paniculata																					0.10	1.0	3.0	6	
	Cinna latifolia																					0.10	1.0	3.0	6	
	Dryas integrifolia integrifolia																					0.10	1.0	3.0	6	
	Eleocharis palustris																					0.10	1.0	2.5	13	

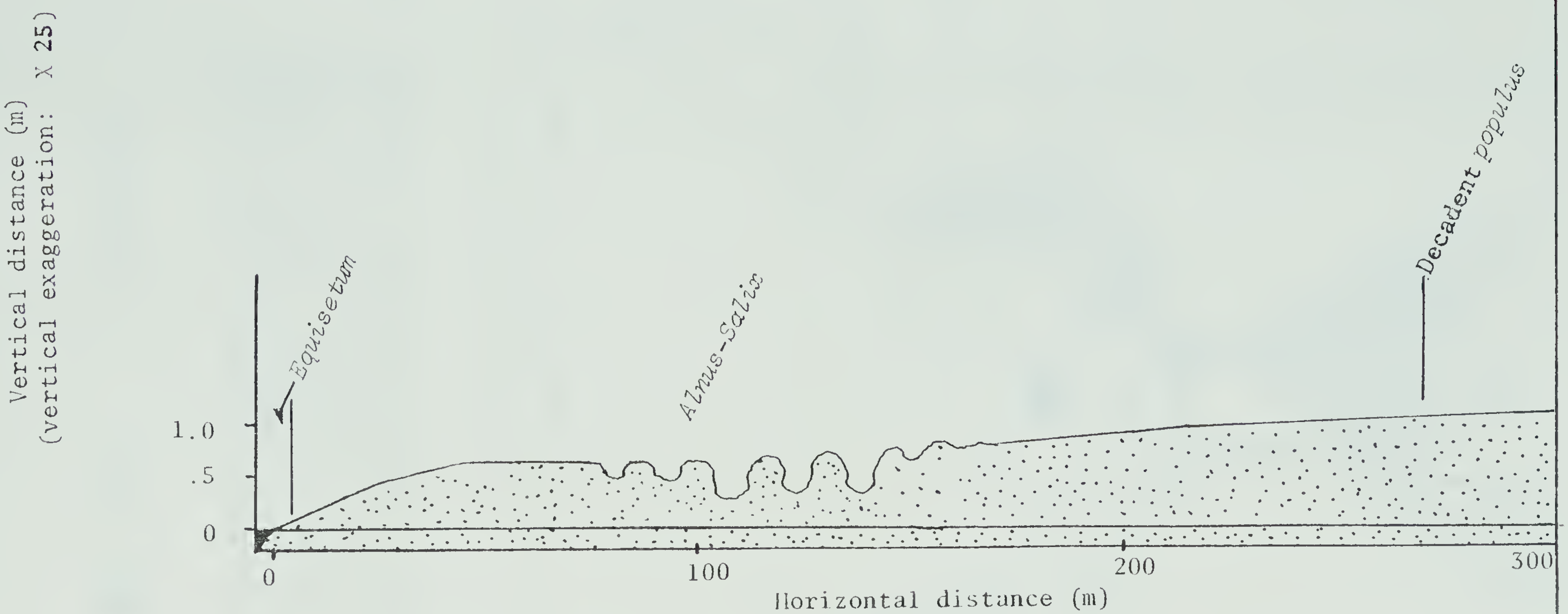


Figure 5.4: Transect 5B. Plant Assemblages (sampled 20 June 1977). The hummocky terrain in the *Alnus-Salix* assemblage is induced by fluvial erosion during flood stage.

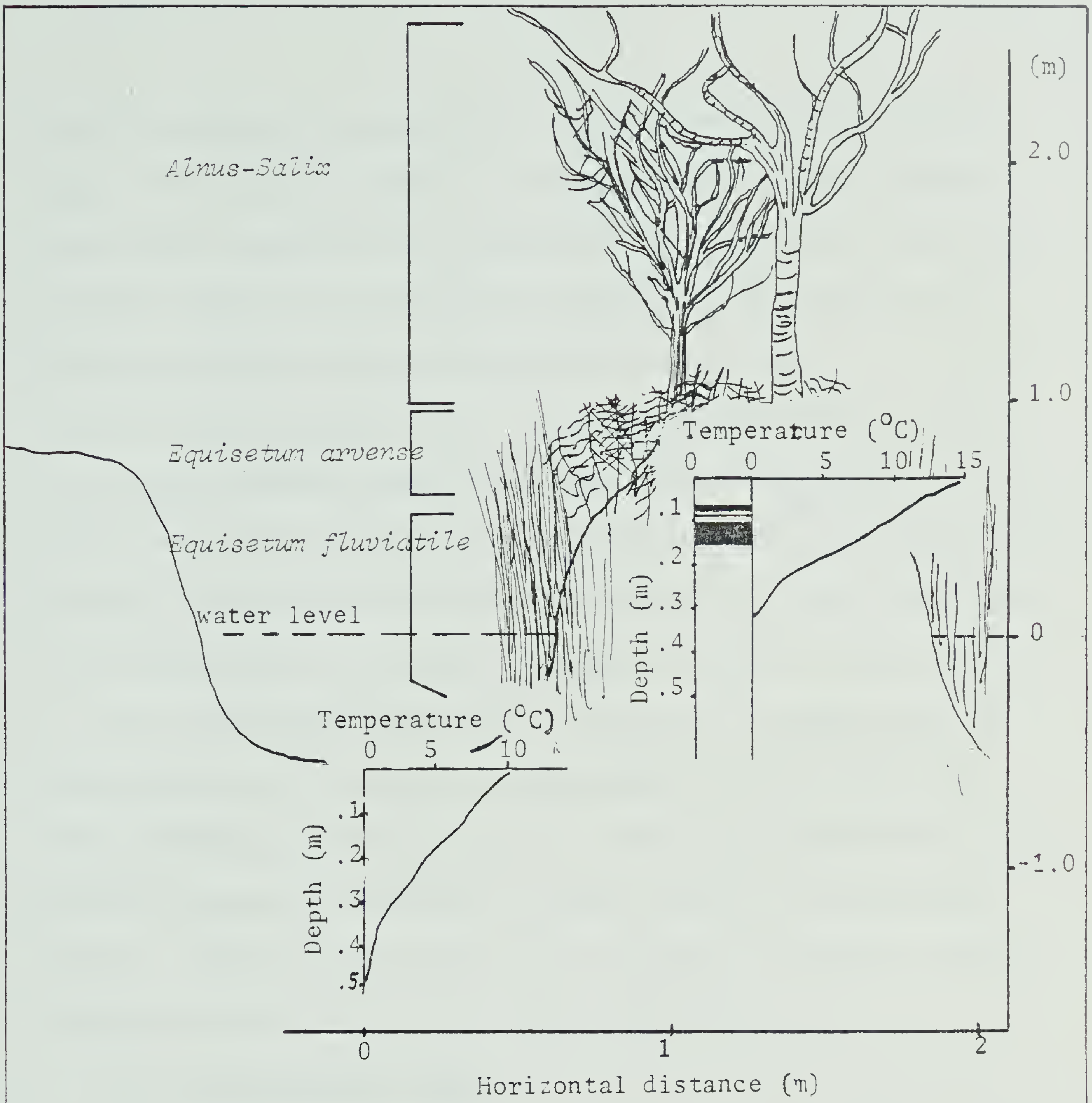


Figure 5.5 : Temperature differences between a hummock and an inter-hummock depression (27 June 1978). Fluvial erosion is the factor responsible for hummock formation. Three soil samples taken from the hummock (5, 20 and 30 cm from surface) had an average soil moisture content of 32.2%.

Alluvium

Mull

degree of uniformity not previously seen in earlier successional stages. This may be related to the decreasing allogenic influence of the river regime on this assemblage. Raup (1975:128) stated that shoreline vegetation in this region displays large differences in species composition which he attributes to flood history. He states that "it is not unlikely that time periods during which the shores (of the Lake Athabasca-Great Slave Lake region) can remain physically stable are shorter than the life spans of most of the perennial plants that make up the shore vegetation. If this is the case, successions in this vegetation are reduced to fragments which, if they exist at all, have indeterminant beginnings and ends." It appears that the plant assemblages occupying elevated portions of the delta which rarely experience flooding are able to develop undisturbed for longer periods of time and consequently allow succession to proceed more normally. This in turn, would help to account for the more uniform composition of the herb layer in this assemblage.

5.13.4 Successional trends

Succession from the *Alnus-Salix* assemblage appears to be directed along two paths, either toward a *Populus* assemblage (as evidenced in Plots 11-2A, JR-2, 9-2, JR-1, 5B-1 and 10-2) or toward an *Alnus* assemblage as indicated by the remaining plots where *Salix* species are being succeeded by *Alnus*.

5.14 *Alnus* assemblage

5.14.1 Distribution

The *Alnus* assemblage is largely restricted to Mouse Island

in the mid delta and some portions of the apex zone south of Steamboat Channel (Figure 5.1). The study plots, with the exception of 6-3 and 5C-2, occupy levees along abandoned channels. Plot 6-3 is located on Rabbit Island (Figure 4.20) and 5C-2 is located inland of a meander scroll-depression along Transect 5C.

5.14.2 Environment

The *Alnus* assemblage occupies landforms on the delta which undergo infrequent flooding, those on Mouse Island each 5-7 years, those on the apex zone very rarely. Most plots sampled occupy levees along abandoned channels which are very protected from wind.

The levees which *Alnus* stands occupy are generally composed of sandy loam having the same average soil moisture content (25%) as the finer grained silt loam of the *Alnus-Salix* assemblage. The finer grained soils would normally be expected to have a greater soil moisture content than sandy loam. The only reasonable explanation may be due to wind exposure. The *Alnus-Salix* occupy more exposed sites where litter accumulating on the ground surface may be subject to removal by the strong onshore winds from Great Slave Lake. *Alnus* sites are very sheltered from the wind and this removal process may not be as efficient. Soil profiles recorded in the *Alnus* sites had an average litter cover of 1.8 cm while the litter layer in the *Alnus-Salix* assemblage sites averaged .5 cm. This process also appears to be reflected in the large percentage of total organic carbon (4.6%) found in the *Alnus* sites. *Alnus-Salix* sites exhibit total organic carbon values average 1.8%.

5.14.3 Vegetation analysis

The floristics of this assemblage is illustrated in Table 5.10. The major difference between the *Alnus-Salix* and *Alnus* assemblage is the decline in significance of *Salix* species so that the *Alnus* assemblage is clearly dominated by *Alnus tenuifolia* (average cover abundance of 30%). *Cornus stolonifera* is the dominant species in the low shrub layer, with an average cover-abundance of 20% while the herb layer is dominated by *Equisetum arvense* with an average cover-abundance of 30%.

5.14.4 Successional trends

The *Alnus* assemblage is largely static in terms of its successional direction as only three plots contained successional species. Plots 18C-1 and 9-5 appear to be succeeding to a *Populus* assemblage while Plot 4-5 is succeeding to the climax *Picea glauca* stage.

The *Alnus* assemblage is not treated separately in the Peace-Athabasca Delta by Dirschl *et al.* (1974). They place *Alnus tenuifolia* within the successional *Salix-Alnus* community. Cordes and Strong (1976) exclude *Alnus* completely from their successional flow model in the Peace-Athabasca Delta. In the Mackenzie Delta, *Alnus* is an active successional species, but only in combination with *Salix* (Gill, 1975a). By contrast, in the Slave Delta, *Alnus tenuifolia* is an important successional dominant.

Table 5.10

Alnus ASSEMBLAGE

Sample Plot Number		18B-3				18E-1				9-5				11-3B			
Stratum	Species	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage
Tree Layer (> 3 m)	*Populus balsamifera*					3	1	3	10	4	1	3	15				
	Picea glauca																
Shrub Layer (> 2.0 m)	*Alnus tenuifolia*	8	4	4	95	7	2	4	70	7	2	4	76	7	3	4	67
	Salix arbusculoides	2	2	2						4	2	3					
	Salix planifolia													1	1	2	
	Picea glauca																
	Populus balsamifera									1	1	2					
	Salix lasiandra																
	Salix interior																
	Salix pseudomonticola													2	2	3	
Shrub Layer (< 2.0 m)	*Cornus stolonifera*	9	4	4	100	8	3	4	100	8	2	4	100	8	4	4	96
	Ribes hudsonianum	4	1	3		3	1	2		2	1	3		2	2	3	
	Rubus melanolasius	5	2	3		2	2	3		1	2	2					
	Rosa acicularis					4	2	3		2	1	3					
	Ribes oxyacanthoides					1	1	3		1	2	3					
	Salix interior																
	Salix planifolia																
	Shepherdia canadensis																
	Ribes hirtellum																
	Salix arbusculoides																
Herb Layer	*Equisetum arvense*	2	1	4	35	7	2	3	90	8	4	4	80				2
	Glyceria grandis	2	3	3		4	2	2									
	Calamagrostis canadensis canadensis	2	2	2													
	Epilobium angustifolium					2	1	2									
	Equisetum palustre																
	Glyceria pauciflora																
	Rubus pubescens																
	Pyrola minor									1	1	3		1	1	2	
	Achillea sibirica					1	1	1									
	Rubus arcticus acaulis																
	Viola sparsifolia	2	1	2													
	Carex rostrata																
	Pyrola secunda secunda													1	1	2	
	Calamagrostis canadensis langsdorffi																
	Platanthera obtusata																
	Ranunculus hyperboreus																
	Caltha palustris																
	Stellaria calycantha calycantha																
	Stellaria calycantha interior																
	Petasites sagittatus																
	Stellaria longifolia																
	Parnassia palustris																

Sample Plot Number		6-3				18D-1				5C-2				18C-2			
Stratum	Species	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage
Tree Layer (> 3 m)	*Populus balsamifera*																
	Picea glauca																
Shrub Layer (> 2.0 m)	*Alnus tenuifolia*	8	4	4	100	9	2	3	100	9	4	4	100	8	4	3	80
	Salix arbusculoides	2	1	3		1	2	2		3	1	3					
	Salix planifolia	2	1	3													
	Picea glauca																
	Populus balsamifera																
	Salix lasiandra					2	2	3									
	Salix interior					3	2	3									
	Salix pseudomonticola																
Shrub Layer (< 2.0 m)	*Cornus stolonifera*	2	2	3	5	6	3	3	87	2	1	2	5	9	3	4	100
	Ribes hudsonianum					5	3	3						1	1	2	
	Rubus melanolasius					2	2	3						3	1	2	
	Rosa acicularis					1	2	2						4	1	2	
	Ribes oxyacanthoides					2	2	3						1	1	2	
	Salix interior					3	2	2									
	Salix planifolia																
	Shepherdia canadensis																
	Ribes hirtellum									1	1	2					
	Salix arbusculoides									1	1	1					
Herb Layer	*Equisetum arvense*	2	1	3	10	8	4	4	100	8	4	4	96	4	1	2	42
	Glyceria grandis					6	3	3						4	2	2	
	Calamagrostis canadensis canadensis																
	Epilobium angustifolium					2	1	2									
	Equisetum palustre	2	1	3						2	1	3					
	Glyceria pauciflora																
	Rubus pubescens																
	Pyrola minor																
	Achillea sibirica													2	1	2	
	Rubus arcticus acaulis																
	Viola sparsifolia																
	Carex rostrata	1	1	2													
	Pyrola secunda secunda																
	Calamagrostis canadensis langsdorffi	1	1	2													
	Platanthera obtusata									1	1	2					
	Ranunculus hyperboreus																
	Caltha palustris																
	Stellaria calycantha calycantha																
	Stellaria calycantha interior																
	Petasites sagittatus																
	Stellaria longifolia																
	Parnassia palustris																

Sample Plot Number		18A-2				5A-1				4-5			
Stratum	Species	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage
Tree Layer (> 3 m)	*Populus balsamifera*												
	Picea glauca									1	1	[illegible]	1
Shrub Layer (> 2.0 m)	*Alnus tenuifolia*	8	2	4	95	7	2	4	66	8	2	4	100
	Salix arbusculoides	4	2	2									
	Salix planifolia									4	2	2	
	Picea glauca									5	2	3	
	Populus balsamifera									2	1	2	
	Salix lasiandra					1	1	3					
	Salix interior												
	Salix pseudomonticola												
Shrub Layer (< 2.0 m)	*Cornus stolonifera*	6	3	4	71	9	4	4	100	2	1	3	19
	Ribes hudsonianum	3	[illegible]	[illegible]		2	3	3		2	2	2	
	Rubus melanolasius	3	2	3		2	1	3		1	2	3	
	Rosa acicularis	1	2	2		1	1	3		1	2	3	
	Ribes oxyacanthoides					1	[illegible]	2					
	Salix interior									1	2	1	
	Salix planifolia									2	2	2	
	Shepherdia canadensis									1	1	2	
	Ribes hirtellum												
	Salix arbusculoides												
Herb Layer	*Equisetum arvense*	4	1	3	61	5	1	2	46	7	2	4	85
	Glyceria grandis												
	Calamagrostis canadensis canadensis					4	1	2		2	1	3	
	Epilobium angustifolium									[illegible]	1	3	
	Equisetum palustre												
	Glyceria pauciflora	4	2	3									
	Rubus pubescens					3	3	3					
	Pyrola minor									1	2	2	
	Achillea sibirica												
	Rubus arcticus acaulis					2	2	3					
	Viola sparsifolia												
	Carex rostrata									1	3	3	
	Pyrola secunda secunda												
	Calamagrostis canadensis langsdorffi												
	Platanthera obtusata												
	Ranunculus hyperboreus	1	3	3									
	Caltha palustris					1	1	3					
	Stellaria calycantha calycantha					1	2	2					
	Stellaria calycantha interior					1	2	2					
	Petasites sagittatus					1	1	2					
	Stellaria longifolia					1	2	3					
	Parnassia palustris					1	1	2					

Sample Plot Number		Averages				
Stratum	Species	Species Significance	Sociability	Vigour	Presence Value (percent)	Total cover (percent)
Tree Layer (> 3 m)	*Populus balsamifera*	0.6	1.0	3.0	18	9
	Picea glauca	0.1	1.0	1.0	9	
Shrub Layer (> 2.0 m)	*Alnus tenuifolia*	7.8	2.8	3.8	100	86
	Salix arbusculoides	1.5	1.7	2.5	55	
	Salix planifolia	0.6	1.3	2.3	27	
	Picea glauca	0.5	2.0	3.0	9	
	Populus balsamifera	0.3	1.0	2.0	9	
	Salix lasiandra	0.5	2.0	3.8	9	
	Salix interior	0.3	2.0	3.0	9	
	Salix pseudomonticola	0.2	2.0	3.0	9	
Shrub Layer (< 2.0 m)	*Cornus stolonifera*	6.3	2.7	3.5	100	70
	Ribes hudsonianum	2.2	1.9	2.7	82	
	Rubus melanolasius	1.7	1.8	2.8	73	
	Rosa acicularis	1.3	1.6	2.6	65	
	Ribes oxyacanthoides	0.5	1.4	2.6	45	
	Salix interior	0.4	2.0	1.5	18	
	Salix planifolia	0.2	2.0	2.0	9	
	Shepherdia canadensis	0.1	1.0	2.0	9	
	Ribes hirtellum	0.1	1.0	2.0	9	
	Salix arbusculoides	0.1	1.0	1.0	9	
Herb Layer	*Equisetum arvense*	5.0	[illegible]	3.3	[illegible]	59
	Glyceria grandis	1.5	2.5	2.5	36	
	Calamagrostis canadensis canadensis	0.7	1.3	2.3	27	
	Epilobium angustifolium	0.5	1.0	2.3	27	
	Equisetum palustre	0.4	1.0	3.0	18	
	Glyceria pauciflora	0.4	2.0	3.0	9	
	Rubus pubescens	0.3	3.0	3.0	9	
	Pyrola minor	0.3	1.3	2.3	27	
	Achillea sibirica	0.3	1.0	1.5	18	
	Rubus arcticus acaulis	0.2	2.0	3.0	9	
	Viola sparsifolia	0.2	1.0	2.0	9	
	Carex rostrata	0.2	2.0	2.5	18	
	Pyrola secunda secunda	0.1	1.0	2.0	9	
	Calamagrostis canadensis langsdorffi	0.1	1.0	2.0	9	
	Platanthera obtusata	0.1	1.0	2.0	9	
	Ranunculus hyperboreus	0.1	3.0	3.0	9	
	Caltha palustris	0.1	1.0	3.0	9	
	Stellaria calycantha calycantha	0.1	2.0	2.0	9	
	Stellaria calycantha interior	0.1	2.0	2.0	9	
	Petasites sagittatus	0.1	1.0	2.0	9	
	Stellaria longifolia	0.1	2.0	3.0	9	
	Parnassia palustris	0.1	1.0	2.0	9	

5.15 *Populus* assemblage

5.15.1 Distribution

With few exceptions, the *Populus* assemblage occupies the mesic environment of elevated levees, particularly cut bank levees. Some *Populus* stands also occur on older levees along pond sloughs (Figure 5.1).

Populus balsamifera, the dominant in this assemblage is an important species on other northern deltas. *Populus* communities occupy the high, well drained levees of the Saskatchewan Delta (Dirschl, 1970), the Peace-Athabasca Delta (Dirschl *et al.*, 1974), and the Colville Delta in Alaska (Bliss and Cantlon, 1957). In the Mackenzie Delta, well developed *Populus* stands occur only on coarse point bar deposits (Gill, 1972a; 1975a).

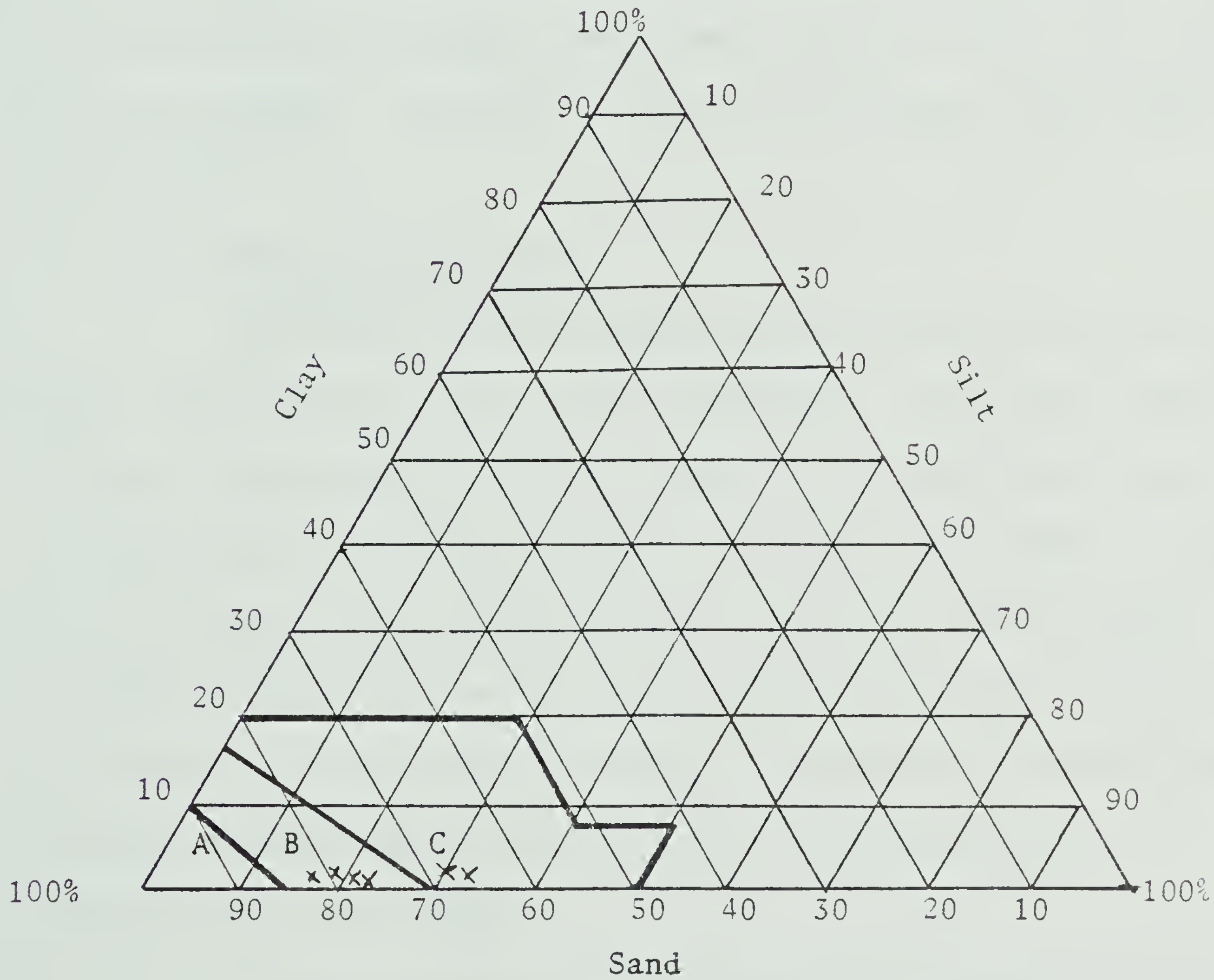
5.15.2 Environment

The relatively coarse texture of the soils and the elevated position of the levees inhabited by balsam poplar aids in creating a mesic soil environment which is required by this species under northern climatic conditions. Figure 5.6 illustrates that soil textures on levees inhabited by balsam poplar are loamy sands and sandy loams. The soil moisture content on these levees averaged 20%, the dryest of any assemblage on the delta. Gill (1972a) found similar soil moisture levels for *Populus* stands in the Mackenzie Delta.

5.15.3 Vegetation analysis

The floristics of this assemblage are illustrated in

Figure 5.6 : Soil textures for *Populus* assemblages



A : Sand
B : Loamy sand
C : Sandy loam

x - - sample

Table 5.11. The tree layer is comprised solely of *Populus balsamifera*, with an average cover abundance for the 6 sampled sites of 85%. The tall shrub layer is dominated by *Alnus tenuifolia* with an average cover abundance of 12% while the low shrub layer is dominated by *Cornus stolonifera* with an average cover abundance of 12%. *Equisetum arvense* dominates the herb and dwarf shrub layer with 95% cover abundance.

Salix species, relatively abundant and in good vigour in most preceding successional assemblages are not as prevalent in the *Populus* assemblage. Where *Salix* species are present, plant vigour is usually poor.

5.15.4 Successional trends

The *Populus* plots sampled in the mid delta zone do not appear to be succeeding to a *Picea* assemblage. The primary reason for this is the inability of white spruce to produce adventitious rooting during the first few years of its life (Gill, 1971). Therefore, in an area such as the mid delta which experiences frequent flooding, the white spruce could not germinate properly and succession to a *Picea* assemblage would not occur. Consequently, succession from the *Populus* assemblage on the mid delta is directed toward a Decadent *Populus* assemblage.

Viereck and Foote (1970) discuss the ecology of *Populus balsamifera* in Alaska and state that along alluvial deposits which experience infrequent flooding, *Populus balsamifera* stands succeed to *Picea glauca*.

Table 5.11 *Populus* ASSEMBLAGE

Stratum	Species	16-1 Species Significance	16-1 Sociability	16-1 Vigour	16-1 Percent total coverage	NC-1 Species Significance	NC-1 Sociability	NC-1 Vigour	NC-1 Percent total coverage	NC-2 Species Significance	NC-2 Sociability	NC-2 Vigour	NC-2 Percent total coverage	9-1 Species Significance	9-1 Sociability	9-1 Vigour	9-1 Percent total coverage	1-1 Species Significance	1-1 Sociability	1-1 Vigour	1-1 Percent total coverage	2-1 Species Significance	2-1 Sociability	2-1 Vigour	2-1 Percent total coverage	Averages Species Significance	Averages Sociability	Averages Vigour	Averages Presence Value (percent)	Averages Total cover (percent)
Tree Layer (> 6 m)	*Populus balsamifera*	8	1	4	85	9	1	4	100	8	1	4	85	7	1	4	80	9	1	4	95	7	1	4	60	8.0	1.0	4.0	100	85
Shrub Layer (> 3 m)	*Alnus tenuifolia*	3	2	3	26	6	2	2	71	4	1	3	17	5	2	3	40	5	2	3	30	7	2	4	85	5.0	1.8	3.0	100	45
	Populus balsamifera	2	1	4		5	1	2		1	1	2		2	1	3						4	1	3		2.3	1.0	2.8	83	
	Salix arbusculoides	3	2	2		1	1	1						2	2	3										1.0	1.7	2.0	50	
	Salix planifolia																					2	1	2		0.3	1.0	2.0	17	
	Picea glauca									1	1	2														0.2	1.0	2.0	17	
	Salix lasiandra	1	1	2																						0.1	1.0	2.0	17	
Shrub Layer (< 2 m)	*Cornus stolonifera*	6	3	4	100	6	2	4	62	7	2	3	100	7	2	4	84	4	1	2	15	2	3	3	13	5.5	2.2	3.3	100	62
	Rosa acicularis	7	2	3		2	2	2		6	2	3		3	2	3						1	1	3		3.2	3.8	2.8	83	
	Rubus melanolasius	3	2	2		2	2	3		1	1	2		1	1	2						1	1	2		1.3	1.4	2.2	83	
	Viburnum edule	4	3	3						1	1	2														0.8	2.0	2.5	33	
	Ribes hudsonianum					3	1	3		1	1	2										1	1	2		0.8	1.0	2.3	50	
	Ribes lacustre					1	1	2						1	1	2										0.3	1.0	2.0	33	
	Salix arbusculoides					1	1	1						1	2	3										0.3	1.5	2.0	33	
	Salix interior													1	1	2										0.1	1.0	2.0	17	
Herb Layer and Dwarf Shrub	*Equisetum arvense*	8	4	4	100	8	4	4	100	7	3	4	71	8	4	4	85	9	5	4	95	8	4	4	97	8.0	4.0	4.0	100	91
	Calimagrostis canadensis canadensis					6	2	3														2	1	3		1.3	1.5	3.0	33	
	Epilobium angustifolium	6	2	3																						1.0	2.0	3.0	17	
	Poa pratensis	2	3	3		3	2	3																		0.8	2.5	3.0	33	
	Actea rubra rubra	3	2	3						2	2	3														0.8	2.0	3.0	33	
	Agropyron trachycaulum	4	1	2																						0.7	1.0	2.0	17	
	Equisetum palustre													2	1	3						1	1	2		0.5	1.0	2.5	33	
	Agropyron pauciflorum	3	3	3																						0.5	3.0	3.0	17	
	Parnassia palustris	2	2	3		1	1	2																		0.5	1.5	2.5	33	
	Actea rubra neglecta									1	2	2										1	1	2		0.3	1.5	2.0	33	
	Pyrola secunda obtusata																					1	3	2		0.1	3.0	2.0	17	
	Pedicularis labradorica																					1	1	2		0.1	1.0	2.0	17	
	Pyrola secunda secunda									1	2	2														0.1	2.0	2.0	17	
	Petasites sagittatus					1	2	2																		0.1	2.0	2.0	17	
	Galium triflorum					1	2	2																		0.1	2.0	2.0	17	
	Glyceria grandis					1	2	3																		0.1	2.0	3.0	17	
	Potentilla norvegica	1	1	2																						0.1	1.0	2.0	17	
	Mertensia paniculata	1	1	2																						0.1	1.0	2.0	17	
	Ranunculus sceleratus	1	1	2																						0.1	1.0	2.0	17	

5.16 Decadent *Populus* assemblage

5.16.1 Distribution

The Decadent *Populus* assemblage usually occupies levees along channels that have long been cut off from active distributaries in the mid delta (Plots 11-2B, 9-4, 5A-3 and 17-1) and portions of the apex zone (Figure 5.1). Decadent *Populus* stands also occupy meander scrolls in the interior portion of Mouse Island.

5.16.2 Environment

The Decadent *Populus* stands on the Slave Delta occupy a unique position on the successional ladder. Since frequent flooding in the mid delta restricts the spread of *Picea glauca* into the understories of *Populus*, the natural succession from *Populus* to *Picea* as reported in the Peace-Athabasca Delta by Cordes and Strong (1976) and Dirschl *et al.* (1974) does not occur in the Slave Delta. Instead the *Populus* assemblage succeeds to a Decadent *Populus* assemblage which can be described quite accurately as the edaphic climax forest in the mid delta zone. These Decadent *Populus* stands are quite old, as evidenced by the large number of dead poplar trees in the sampled and observed stands.

The Decadent *Populus* assemblage in the Slave Delta differ slightly from those reported by Gill (1971) on the Mackenzie Delta. The *Populus* stands in the Mackenzie Delta become 'decadent' when flooded during lateral migration of point bars and occupation in meander depressions. Those stands in the Slave Delta would more correctly be termed 'stagnant' as the natural succession has been

terminated by frequent flooding. The term 'decadent' will suffice for the Slave Delta because the stands are visibly deteriorating.

In the sampled Decadent *Populus* stands the soil climate appears to be quite different from the Poplar stands. For example, the ground frost in Decadent *Populus* stands remains substantially longer than in *Populus* assemblage. The poplar stand sampled beside the basecamp on Steamboat Channel (Transect 1, Plot 1-1) on 30 May 1977 had ground frost located 50 cm below the ground surface. One week later (7 June), this frost had thawed. Decadent *Populus* stands sampled along Transect 1 had ground frost less than 10 cm from the surface on 30 May 1977; depth to ground frost one week later remained basically the same.

5.16.3 Vegetation analysis

Table 5.12 illustrates the floristics of the Decadent *Populus* assemblage. The tree layer is dominated by *Populus balsamifera* with an average cover abundance of 80%. The shrub layer is dominated in all plots by *Cornus stolonifera* with an average cover abundance of 20%. *Alnus tenuifolia* and *Ribes hudsonianum* are also prominent and occur in each plot with an average cover abundance of 6%. *Equisetum arvense* is the dominant herb with an average cover abundance of 50%.

5.16.4 Successional trends

The Decadent *Populus* stands sampled, as well as others observed in the field appear to be static and show little evidence of succession to the climax *Picea* assemblage, as no spruce seedlings

Table 5.12 Decadent *Populus* ASSEMBLAGE

Sample Plot Number		17-4				11-2B				9-4				5A-3				Averages				
Stratum	Species	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Presence Value (percent)	Total cover (percent)
Tree Layer (> 6 m)	*Populus balsamifera*	8	1	4	90	6	1	4	50	8	1	4	85	9	1	4	100	7.8	1.0	4.0	100	82
Shrub Layer (> 2 m)	*Alnus tenuifolia*	1	1	2	1	4	2	3	25	2	2	2	5	6	1	3	45	3.3	1.8	2.5	100	19
	Salix pseudomonticola					3	1	3										0.8	1.0	3.0	25	
Shrub Layer (< 2 m)	*Cornus stolonifera*	4	2	3	100	5	1	3	56	8	1	4	100	9	2	4	100	6.5	1.5	3.5	100	98
	Rosa acicularis	8	2	4		3	1	3		2	1	2						3.3	1.3	3.0	75	
	Ribes hudsonianum	6	3	3		2	2	3		2	1	3		1	1	3		2.8	1.8	3.0	100	
	Ribes oxyacanthoides	4	3	3		2	1	3		1	1	3						1.8	1.7	3.0	75	
	Alnus tenuifolia	1	1	2						1	1	1		4	2	2		1.5	1.3	1.7	75	
	Viburnum edule					2	3	3										.5	2.0	3.0	25	
	Salix arbusculoides									1	3	2						.3	3.0	2.0	25	
	Rosa woodsii													1	1	2		.3	2.0	1.0	25	
Herb Layer	*Equisetum arvense*	8	4	4	92	4	1	3	36	8	4	4	86	7	4	4	75	6.8	3.3	3.8	100	72
	Calamagrostis canadensis canadensis	2	1	2		3	1	3										1.3	1.0	2.5	50	
	Epilobium angustifolium	2	1	3		2	1	3										1.0	1.0	3.0	50	
	Geocaulon lividum					2	1	3										0.5	1.0	3.0	25	
	Pyrola asarifolia					1	2	3										0.3	2.0	3.0	25	
	Pyrola minor									1	1	2						0.3	1.0	2.0	25	

were observed in any location. The bryophyte layer, well developed in spruce stands, is poorly developed in the Decadent *Populus* assemblage. These sites may eventually succeed to a *Picea* assemblage but there is no present indication of this.

5.17 *Picea* assemblage

5.17.1 Distribution

The distribution and ecology of *Picea glauca* forests in northern alluvial habitats is well documented (Jeffrey, 1961; Savile, 1963; Dirschl, 1972; Strang, 1973; Dirschl *et al.*, 1974; Gill, 1975a; Cordes and Strong, 1976).

The *Picea* assemblage occupies most of the older, elevated portions of the apex zone (Figure 5.1). East of the main distributary of Resdelta Channel, *Picea* assemblages have invaded portions of levees along open ponded sloughs or open channels draining into the Slave River from the Jean River (which originates from the Slave River upstream from the apex). A sampled site on the Jean River (Table 5.1, Plot JR-3) is an example of this. The other plots are located in the apex zone north of Nagle Channel.

5.17.2 Environment

The environment which the *Picea* assemblage inhabits and the influence the assemblage has upon its habitat is discussed in Section 4.4.3.

5.17.3 Vegetation analysis

Table 5.13 illustrates the floristics of the *Picea* assemblage on the Slave Delta. All sampled sites are dominated by *Picea*

glauca with an average cover abundance of 95%. In all plots, there is a secondary growth of *Picea glauca* which has an average cover abundance of only 5%. The shrub layer in the *Picea* assemblage sites is dominated by *Rosa acicularis* with an average cover abundance of 25%. Other shrubs present in most of the sampled plots are *Alnus tenuifolia* (average cover abundance of 5%), *Cornus stolonifera* (5%) and *Viburnum edule* (3%). Equisetum arvense dominates the herb and dwarf shrub layer with an average cover abundance of 30%. *Pyrola secunda secunda* (7%) and *Linnaea borealis* (5%) are present in good numbers as well.

With the exception of one plot (4-1), the bryophyte layer (Table 5.1) is dominated by *Hylocomnium splendens* with an average cover-abundance of 35%. *Aulacomnium palustre* is present in the assemblage with an average cover-abundance of 50% in the plots where it is present.

5.17.4 Successional trends

As the *Picea* assemblage is the successional climax assemblage on the Slave Delta, natural succession has effectively stopped. In disturbed portions of the *Picea* assemblage secondary succession is occurring and will be discussed in section 5.18.

5.18 Secondary succession

Secondary succession is occurring on old skidding stations along the levees of Nagle Channel, old abandoned roads connecting these stations and occasional logging roads built through spruce stands.

Table 5.13

Picea ASSEMBLAGE

Sample Plot Number		4-1				16-4				JR-3				16-2				16-3				4-6				Averages				
Stratum	Species	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Percent total coverage	Species Significance	Sociability	Vigour	Presence Value (percent)	Total cover (percent)
Tree Layer (> 3 m)	*Picea glauca*	7	1	4	80	7	1	4	65	8	1	4	75	6	1	4	50	7	2	4	70	9	4	4	100	8.8	1.7	4.0	100	73
	Populus balsamifera	5	1	3		2	1	2														1	1	2		1.6	.5	2.3	50	
Shrub Layer (> 2 m)	*Picea glauca*	1	1	3	21	1	1	2	60	2	1	3	21	1	1	2	56	2	1	3	12	2	1	2	15	1.5	1.0	2.5	100	31
	Populus balsamifera					2	1	2		1	1	2						1	1	2						.7	1.0	2.0	50	
	Alnus tenuifolia	4	2	3		5	1	3		3	1	2		6	2	3		2	2	3		3	1	2		3.8	1.5	2.7	100	
	Salix arbusculoides					4	2	3		2	2	2		4	2	3		1	2	3						1.8	2.0	2.8	67	
Shrub Layer (< 2 m)	*Rosa acicularis*	6	3	4	62	7	3	3	76	6	2	3	75	6	2	3	86	7	2	4	66	9	4	4	100	6.8	2.7	3.5	100	78
	Cornus stolonifera	4	2	3						3	2	2		6	2	3		1	1	2						2.3	1.8	2.5	67	
	Viburnum edule	3	2	3		2	1	2		3	1	3		1	2	2						2	1	3		1.8	1.4	2.6	83	
	Ribes hudsonianum					2	2	2		2	1	2		2	1	2		2	1	2						1.3	1.3	2.0	67	
	Ribes oxycanthodes									2	2	2										1	1	2		.5	1.5	2.0	33	
	Shepherdia canadensis									2	2	2										1	1	2		.5	1.5	2.0	33	
	Salix arbusculoides					2	1	3																		.3	1.0	3.0	17	
	Rubus melanolasius	1	1	2		1	2	2																		.3	1.5	2.0	33	
	Ribes triste	1	1	2																						1	1.0	2.0	17	
Herb and Dwarf Shrub Layer	*Equisetum arvense*	8	4	4	100	8	4	4	100	2	1	2	100	7	2	4	100	4	1	2	65	3	1	3	75	5.3	2.2	3.2	100	90
	Geocaulon lividum					5	2	3		7	2	4		2	1	3		6	2	4		1	1	2		3.5	1.6	3.2	83	
	Pyrola secunda secunda					5	3	3						2	2	3		6	3	3		2	2	2		2.5	2.5	2.8	67	
	Linnaea borealis	1	2	3						6	3	3										5	4	3		2.0	3.0	3.0	50	
	Fragaria virginiana					5	2	3						3	2	3		2	5	3						1.7	3.0	3.0	50	
	Pyrola grandiflora									7	3	4														1.2	3.0	4.0	17	
	Glyceria grandiflora									7	3	4														1.2	3.0	4.0	17	
	Epilobium angustifolium					3	1	2		2	1	2										1	1	2		1.0	1.0	2.0	50	
	Cornus canadensis																					4	3	3		.7	3.0	3.0	17	
	Pyrola secunda obtusata					2	2	3						2	1	3										.7	1.5	3.0	33	
	Glyceria borealis					3	2	3						1	2	2										.7	2.0	2.5	33	
	Platanthera obtusata	1	1	3		2	1	1						1	1	3										.7	1.0	2.3	50	
	Pyrola minor	3	2	3																						.5	2.0	3.0	17	
	Pedicularis labradorica	3	1	3																						.5	1.0	3.0	17	
	Calamagrostis canadensis canadensis					3	2	3																		.5	2.0	3.0	17	
	Pyrola asarifolia																					3	2	3		.5	2.0	3.0	17	
	Arctostaphylos uva-ursi	2	2	3																						.3	2.0	3.0	17	
	Selaginella selaginoides																					2	3	2		.3	3.0	2.0	17	
	Stellaria calycantha calycantha													1	2	2										.3	2.0	2.0	17	
	Moneses uniflora					2	2	3																		.3	2.0	3.0	17	
	Rubus arcticus acaulis	1	2	2																						.2	2.0	2.0	17	
	Achillea sibirica	1	1	3																						.2	1.0	3.0	17	

Secondary succession was also recorded along Transect 16 where a *Picea* stand has been selectively cut.

5.18.1 Skidding stations

Eight abandoned skidding stations are found along the levees of the right bank of Nagle Channel. The vegetation of one of these stations was analyzed and compared to an adjacent undisturbed site. Both sites (Table 5.1, NC-1, disturbed and NC-2, undisturbed) are inhabited by *Populus* assemblages.

5.18.1.1 Vegetation analysis and successional trends

A comparison of the floristics of these 2 plots is illustrated in Table 5.11. Though the borders of the plots are within 50 m of each other, there are significant differences in species composition.

The tree layer exhibits little difference in cover-abundance and composition. *Populus balsamifera* dominates in both sites with identical cover abundance values of 85%. The age of this species is significantly different between plots. In the disturbed site the maximum age of the tree was 13 years, its height was 7.3 m with a DBH of 7.6 cm. In the undisturbed site a balsam poplar of similar height (7.5 m) and DBH (10 cm) was 55 years of age.

The tall shrub layer is dominated in the disturbed site by *Populus balsamifera* with a cover abundance of 30%; the undisturbed layer is dominated by *Alnus tenuifolia* with a cover abundance of 15%. There is slight indication of a successional trend toward the *Picea* assemblage in the undisturbed site with the occurrence

of three small *Picea glauca*.

The low shrub layer is dominated in both sites by *Cornus stolonifera* with cover abundance values of 40% for the disturbed site and 75% for the undisturbed site. Total percentage cover of the disturbed plot has somewhat greater coverage of 85%.

The herb and dwarf shrub layer is dominated by *Equisetum arvense*; 90% cover in the disturbed site and 70% cover in the undisturbed site. The disturbed site has 7 species in this layer, the undisturbed plot has 2.

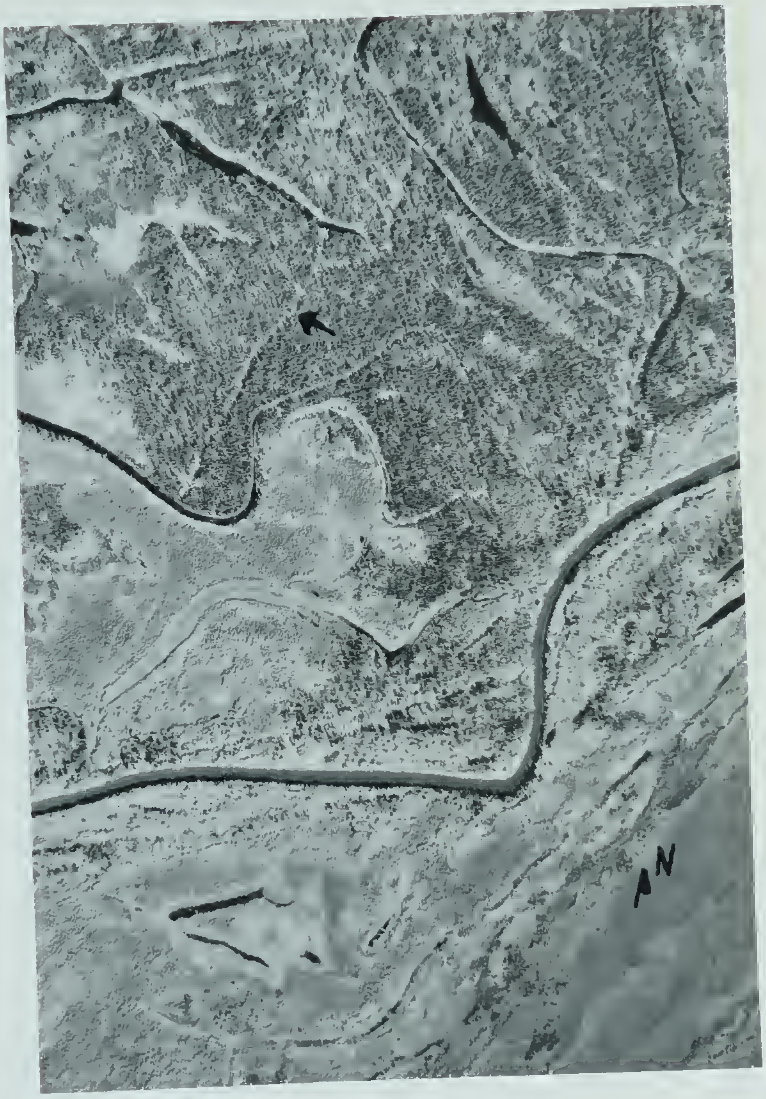
5.18.2 Logging roads

The difference between the vegetation growing along an old logging road and the surrounding *Picea* forest sampled along Transect 4 are very obvious in Plate 21. Plate 22 is an aerial view of a portion of the *Picea* forest north of Nagle Channel showing the distribution of abandoned logging roads, the arrow indicates the site (Plot 4-7) illustrated in Plate 21.

5.18.2.1 Vegetation analysis and successional trends

The composition and structure of the *Salix-Equisetum* assemblage growing on the disturbed site are shown in Table 5.6 (Plot 4-7). The maximum age of the *Salix interior* growing on the sampled site was 11 years, suggesting the road was abandoned around 1966. A portion of this road has standing water on it, which suggests that the road bed has subsided through thermokarst erosion by surface disturbance. The depth of thaw on the road was greater than 1.5 m on 11 June 1977, while thaw depth in the adjacent undis-

Plate 21: Surface view of a logging road shown in Plate 22. The transition from a Climax *Picea* assemblage to a *Salix-Equisetum* assemblage is abrupt along the disturbed surface (14 June 1977).



100 m

Plate 22: Panchromatic aerial photograph illustrating the abandoned logging road (arrow) sampled along Transect 4.

Courtesy, Canadian Wildlife Service.

turbed *Picea* assemblage was .35 m.

Although less than 5% of the sampled plot contained *Populus balsamifera*, its presence and excellent vigour are indicative of probable succession towards a *Populus* assemblage. A solitary occurrence of *Picea glauca* in excellent vigour suggests a short lived dominance by a *Populus* assemblage and succession to a *Picea* stand.

5.18.3 Selective logging - Transect 16

The three plots sampled in the *Picea* stands along Transect 16 (16-2, 16-3 and 16-4) have been selectively logged (approximately 25-30 years ago - G. Lafferty, Pers. Comm., 1977). Selective logging as opposed to clear cutting implies that only the best trees are felled and the younger trees or trees with substantial rot are left standing. This is typical of small logging operations (Ted McIntosh, Pers. Comm., 1976). Table 5.13 illustrates the floristic differences between undisturbed *Picea* stands (Plots 4-1, 4-6 and JR-3) and the disturbed sites.

Although differences in species composition between the disturbed and undisturbed sites are minimal there are a few notable differences. *Linnaea borealis* is present only in the undisturbed *Picea* stands sampled. This was the case for all *Picea* assemblage stands observed in the field. *Fragaria virginiana* on the other hand is present only in the disturbed *Picea* sites.

Structural differences are most evident in the tree layer and the tall shrub layer. The undisturbed sites have a far

greater average total percentage cover in the tree layer than the disturbed sites (87% as opposed to 65%). The tall shrub layer in the disturbed sites has an average total percentage cover of 42% vis-a-vis 12% for the undisturbed sites.

CHAPTER SIX

IMPLICATIONS OF UPSTREAM HYDROELECTRIC DEVELOPMENT

6.1 Introduction

If constructed, a proposed dam on the Slave River at Mountain Rapids 10 km south of Fort Smith, N.W.T. will substantially alter the natural regime of the river and disrupt the continued downstream progradation of the Slave River Delta. The various proposals to dam the Slave River are discussed in section 1.5.

6.2 The dam

Although no decision has been made at this time concerning which variation of dam construction will be implemented, if government approves the project, it is assumed by the author that the most economical versions would be considered. The two larger proposals would make maximum use of the potential water resource, and because of their size, produce more power at less cost per kilowatt hour (Table 1.1). The potential impacts of the largest of the two most economical structures will therefore be assessed. This larger structure will maintain a mean water level of 209.1 m a.s.l. (a maximum of 210.1 m a.s.l. and minimum of 208.2 m a.s.l.), 36.9 m above the present mean river level at the proposed dam site and 54.0 m above the mean level of Great Slave Lake (155.1 m a.s.l.)[1].

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[1] Montreal Engineering, 1978.

6.2.1 Hydrological implications

The initial disturbance of the river regime will occur during the impoundment period when the reservoir is being filled. Downstream effects depend upon the amount of discharge reduction during the initial impoundment period, and the season during which the reservoir is filled.

The secondary but more important and longer lasting disturbance is that resulting from the reduction of bedload and suspended sediment as these materials would be deposited in the reservoir created by the dam.

Increased erosion can be expected downstream of the dam as the river trys to regain equilibrium; sediment-free water has more erosive capability. The degree of downstream erosion depends largely on the amount and cyclicity of discharges to be allowed past the dam. If the discharges and their variability are small, then consequent erosion may be negligible (B. Rains, Pers. Comm., 1978).

The discharge of the Slave River after impoundment will be dictated by plant operating strategies (Montreal Engineering, 1978). Such strategies reflect the demands of the market to which the electrical energy is being sold, plus adjustments to natural discharge variations of high magnitudes. If, for instance, the main market was the City of Edmonton, power demand would be greatest during the winter months. Consequently, before freeze-up the reservoir would be filled to its maximum level and at breakup the water level of the reservoir would be depleted, a product of the winter demand for

energy and low winter discharge values (Figure 6.1). Because of the probable reduction in water levels in the reservoir through the winter and the need to refill the reservoir, the normal spring flood levels downstream of the dam would be reduced.

Whether the spring flood is at normal levels or not, the large reduction in sediment would affect the erosion and deposition regime of the river and delta and subsequently affect the ecology of the delta.

6.2.2 Initial impoundment period

In order to calculate the duration of the initial impoundment period, it is necessary to evaluate the volume of the proposed reservoir, and the amount of time required to fill it. The time factor depends upon two variables, the season when the reservoir will be filled and the plant operating strategy at the time - that is, whether the Slave River will be closed off completely until the reservoir is filled or whether it will be permitted to discharge at a restricted rate, causing the reservoir to fill over a longer period of time.

6.2.3 The volume of the reservoir

Figure 6.2 illustrates a model of the proposed 'variation 3' dam reservoir. The reservoir width was calculated from a series of topographical sheets[1]. The mean width of 6.9 km was derived by averaging 50 widths of the actual reservoir outline drawn by the

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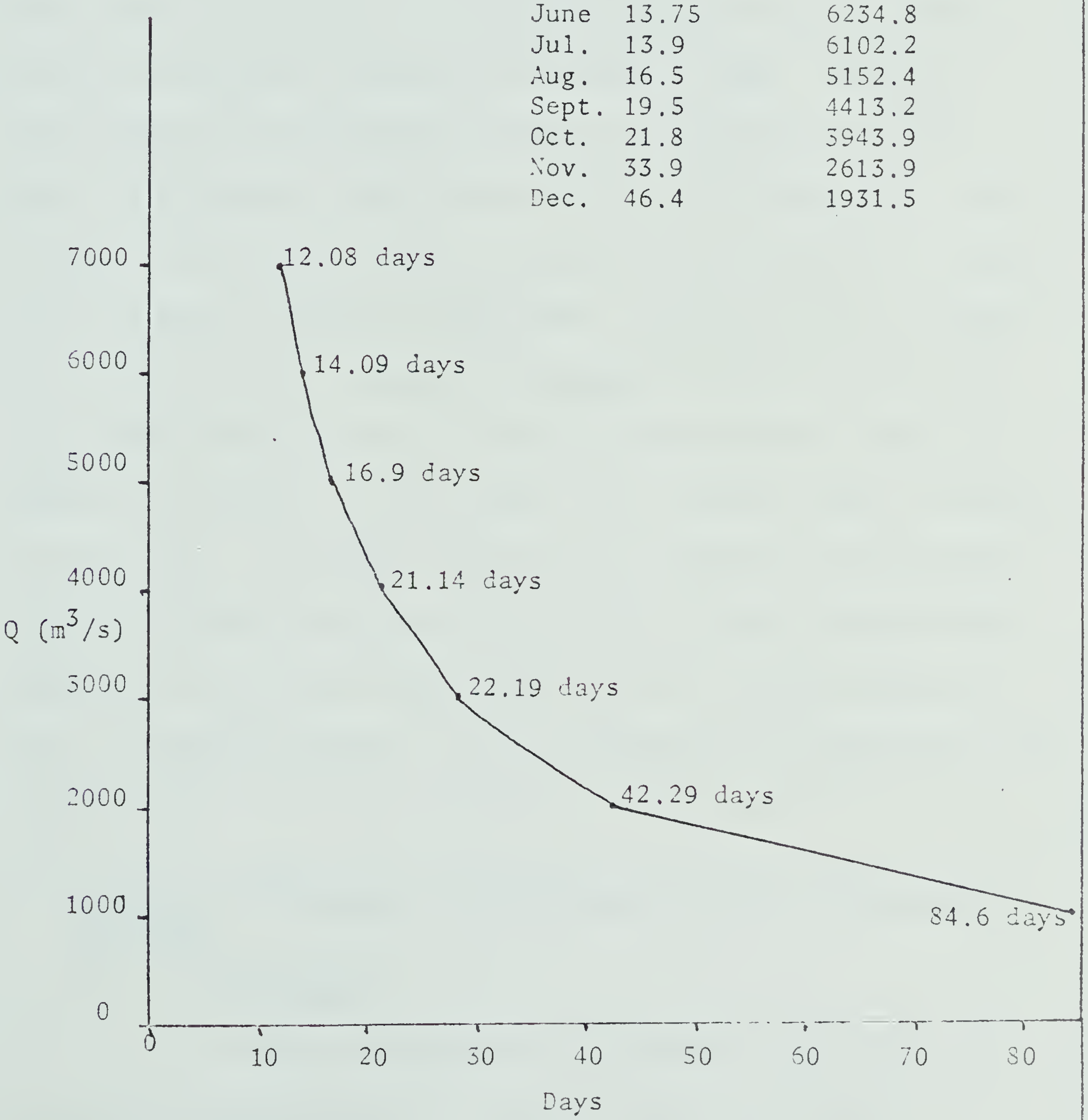
[1]Topographical sheets 75H, 74E, Canada Department Mines and Surveys (1971).

Figure 6.1 : Initial impoundment period for 'Variation 3' dam reservoir - duration required to fill the reservoir to the mean elevation of 209.1m a.s.l. given certain discharges.

months	initial impoundment period	mean monthly Q for all recorded years m^3/s
Jan.	53.25 days	1783.3
Feb.	55.5	1714.5
Mar.	63.3	1514
Apr.	51.75	1779.9
May	18.4	4694.1
June	13.75	6234.8
Jul.	13.9	6102.2
Aug.	16.5	5152.4
Sept.	19.5	4413.2
Oct.	21.8	3943.9
Nov.	33.9	2613.9
Dec.	46.4	1931.5



author at a mean water level of 209.1 m a.s.l. It was calculated (as shown in Figure 6.2) that the reservoir should hold approximately 7,308,756,000 m^3 of water above the average volume of water naturally present within the boundary of the proposed reservoir.

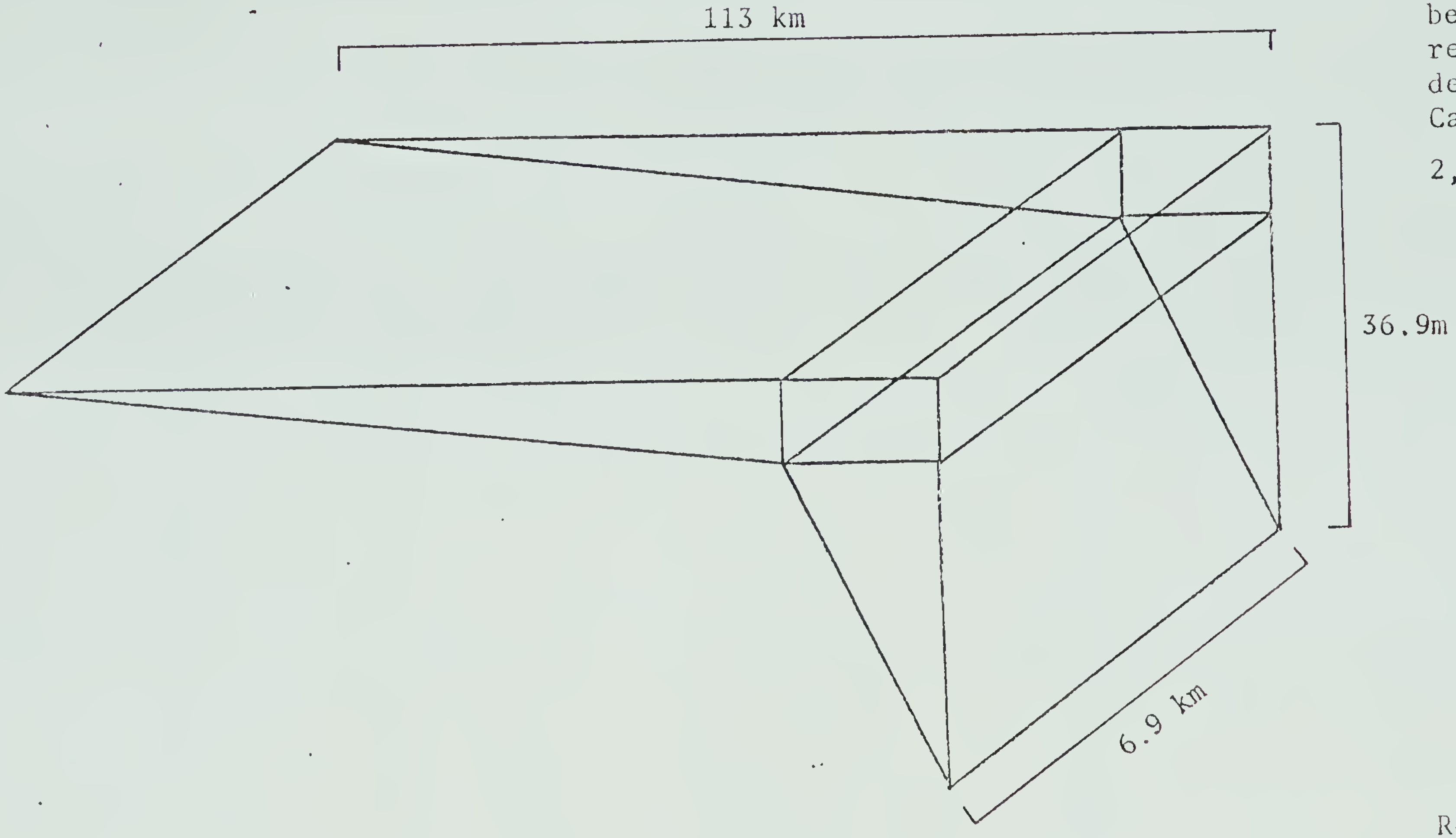
In order to fill the reservoir to the prescribed mean water level of 209.1 m a.s.l., the discharge below the dam would be entirely or partially shut off for a period of time. Figure 6.1 illustrates the relationship between the discharge of the Slave River and the number of days the reservoir would take to fill. Also included is the amount of time the reservoir would take to be filled given the mean discharge for each month calculated for all available Slave River discharge values. For example, if the Slave River was closed off entirely during the month of June which has a mean discharge of 6,234.8 m^3/s (n = 23 years), the reservoir would be filled in 13.75 days. If, however, the river was allowed to discharge 50% of its normal flow during June, 3,117.4 m^3/s of water would be discharged down river and an equal amount would be retained behind the dam. By employing Figure 6.1 we may estimate that the dam would then take 27.75 days to fill to the mean water level of 209.1 m a.s.l.

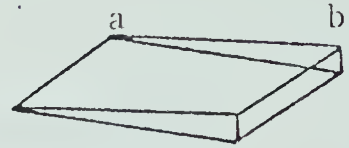
6.3 Potential environmental consequences of initial impoundment on the delta

6.3.1 Introduction

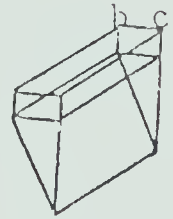
In order to evaluate the environmental consequences of the initial impoundment period, Table 6.1 has been constructed to illustrate the relationships between the season of the year when the

Figure 6.2 : Geometrical model of proposed Mountain Rapids dam reservoir on the Slave River[1]





Reservoir volume between (a) upper reach mear Riviere des Rochers, and Cassette Rapids (b) 2,471,166,000 m^3



Reservoir volume betweem (b) Cassette Rapids and the dam structure (c) at Mountain Rapids, 4,837,590,000 m^3

1. Assuming mean elevation of 209.1 m a.s.l. at dam head.

Table 6.1: Initial Impoundment Period and Possible Environmental Consequences on the Slave River Delta.

		SPRING (May-June)		SUMMER (July-Aug.)		FALL (Sept.-Oct.)		WINTER (Nov.-Dec)	
Duration		16.1 days	3.1	15.2 days	2.1	20.7 days	2.3	42.3 days	2.2
	A	5		0		0		0	
100% closure	B	0		0		2		5	
	C	1		0		0		5	
	D	5		0		0		3	
	E	5		5		4		3	
	F1	5		5		5		0	
	F2	5		5		5		1	
	G	1		1		2		0	
	H1	4		0		5		5	
	H2	0		5		0		0	
Duration		21.0 days	3.0	20.3 days	2.0	27.5 days	1.9	67 days	1.9
	A	5		0		0		0	
75% closure	B	0		0		2		3	
	C	0		0		0		5	
	D	5		0		0		3	
	E	5		5		4		3	
	F1	4		4		3		0	
	F2	5		5		4		1	
	G	2		2		2		0	
	H1	4		0		4		4	
	H2	0		4		0		0	

		SPRING (May-June)		SUMMER (July-Aug.)		FALL (Sept.-Oct.)		WINTER (Nov.-Dec.)	
Duration		32.3 days	2.8	31.0 days	1.9	42.1 days	1.8	100 days	1.3
	A	3		0		0		1	
50% closure	B	0		0		3		1	
	C	0		0		0		2	
	D	5		0		0		3	
	E	5		5		4		2	
	F1	3		3		3		0	
	F2	5		5		3		1	
	G	3		3		2		0	
	H1	4		0		3		3	
	H2	0		3		0		0	
Duration		71.3 days	2.1	67.7 days	1.7	83.7 days	1.9	190 days	1.3
	A	1		0		0		2	
25% closure	B	0		0		5		1	
	C	0		0		2		1	
	D	3		0		0		1	
	E	3		3		2		2	
	F1	3		3		2		1	
	F2	5		5		3		2	
	G	4		4		3		1	
	H1	2		0		2		2	
	H2	0		2		0		0	

KEY:
A Disruption of Breakup: Range 0-5 (0: Nil; 5: Extreme)
B Disruption of Freezeup: Range 0-5
C Disruption of Channel ice Formation:Range 0-5
D Disruption of Spring Flood: Range 0-5
E Lowering of Great Slave Lake Water levels: Range 0-5
F Sediment Reduction 1: Suspended Sediment (Range 0-5) 2: Bedload
G Erosion (Increase) on Delta Landforms, Range 0-5
H Modification of Microclimate: 1 Cooling 2 Warming (Range 0-5)

river water would be impounded, the duration of the initial impoundment period, and the probable corresponding environmental consequences of the defined closure duration and season.

6.3.2 Disruption of breakup

If the dam impounds the complete discharge during spring, the breakup of ice in the delta distributaries would be delayed for the entire impoundment period as the spring surge of water is the principal factor promoting breakup. If the duration of the initial impoundment period is lengthened by increasing discharge, the disruption factor will drop in proportion to the increase.

6.3.3 Disruption of freeze-up

Retention of Slave River water during early winter (November, as defined in Table 6.1) would result in more rapid cooling of the exposed channels, permitting the invasion of ground frost where previously prevented. Complete closure of river discharge for the period required to fill the reservoir in the early winter would mean that channels along the outer delta previously affected by a continuous input of relatively warm river water would be occupied by colder, static Great Slave Lake water. The shallow channels and sloughs would consequently experience more widespread freezing. Channel sections less than 1.25 m deep[1] would freeze to the bottom. The subsequent release of river water from the dam after the initial impoundment period would flood over the frozen channels and add to

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[1]River ice in the distributary channels sampled 26 April 1978 reached a maximum depth of 1.25 m.

the thickness of the ice because of the cold air temperatures during this time of year, resulting in the buildup of icings. The formation of thick ice on the flood plain would retard spring breakup as the ice buildup would take substantially longer to melt.

6.3.4 Disruption of channel ice formation

An increase in the thickness of channel ice may also result if the impoundment period begins in the winter months after initial ice formation on the channels has begun, especially if the discharge is decreased by 50%. In this case, formation of black ice (see section 4.1) may be promoted because decreased velocity of the discharging water would allow freezing at a faster rate. Decreased velocity would also promote increased 'C'-Axis development of the black ice crystals (Adams, 1976).

6.3.5 Disruption of the spring flood

Complete closure of the dam during the spring would obviously eliminate the spring flood in the delta and thereby retard breakup and reduce spring temperatures. This in turn would negatively affect the phenology of the delta's vegetation.

6.3.6 Lowering of Great Slave Lake water levels

The relationship between the discharge of the Slave River and corresponding Great Slave Lake water levels was discussed in section 4.1. A reduction in the mean monthly discharge of the Slave River would have important effects on the levels of the lake. A reduction in river and lake levels would affect the ecology of the outer delta if the duration was of sufficient length.

By employing the equation $Y = .82 + .79 \times 10^{-4}X$ (section 4.1) the effect of reduced river discharge on the level of Great Slave Lake can be predicted given the plant operating strategy. For example, if the river discharge is completely shut off for 13.75 days in June (Figure 6.1) and allowed to discharge at the calculated mean monthly rate of 6,234.8 m^3/s for the remainder of the month, the level of Great Slave Lake would be reduced (mean monthly value) 18 cm below the August 1977 low summer water level. As a result most of the cleavage bar islands of the outer delta would not be flooded during spring. Lowering of Great Slave Lake water levels would result from all versions of impoundment, as illustrated in Table 6.1. The extent of lake level lowering would depend upon the season and duration of the initial impoundment period.

6.3.7 Sediment reduction

Several authors have described the consequences of reduced sediment load in rivers below a reservoir (Taylor *et al.*, 1972; Gill, 1973; Kellerhals and Gill, 1973; Wiebe and Drennan, 1973; Geen, 1974).

Sediment reduction would be of greatest consequence during the ice free period. It would have far-reaching consequences beyond the initial impoundment period; these are discussed in section 6.5.

6.3.8 Erosion of delta landforms

A reduction of bedload and suspended sediment below the dam would increase the erosive force of the river as it tries to

regain equilibrium. The potential erosive force of the river on the delta is an unknown quality largely because the river would regain part of its total potential sediment load from bed and bank scouring between the dam and the apex of the delta. The effects of sediment reduction is discussed in section 6.5.3 as this factor would have a long-term effect on the river regime below the dam.

6.3.9 Modification of microclimate

During the initial impoundment period, the growing season on the delta could be shortened because of the delay in spring break-up.

6.4 Ecological consequences of initial impoundment period

6.4.1 Introduction

Ecological disruptions caused by the initial impoundment would most likely be minimized if discharge downstream of the dam would be kept close to normal levels. However a major lowering of normal water levels for a particular season could result in ecological problems similar to those that occurred in the Peace-Athabasca Delta upon closure of the W.A.C. Bennett Dam (Reinelt *et al.*, 1971). The period of time it would take to fill the proposed reservoir to the prescribed level would be too short to effect major ecological changes in the delta (Townsend, 1972; Cordes and Strong, 1976), but successional trends could be initiated during this period which would result in major vegetation changes at a later date.

6.4.2 Consequences for wildlife habitat

Immediate impacts of the initial impoundment could be felt

by animal life which depend upon normal seasonal river levels. Musk-rats, for example would be frozen out of their habitat if water levels were dropped considerably in the fall or winter months (Reinelt *et al.*, 1971).

A major reduction of the spring flood would result in lower water levels in the interlevee depressions of cleavage bar islands. This would greatly reduce waterfowl nesting and feeding habitat. Lowering of water levels during the fall months would reduce aquatic and emergent habitats used by local and migrating waterfowl for feeding and staging.

Emergent vegetation that occupies the littoral zones of active and inactive distributaries would decrease in productivity if the water levels were lowered. This vegetation is a major source of food for muskrat in the delta (Law, 1950).

Lowering of water levels in the fall will coincide with the reproduction period of whitefish (*Coregonus clupeaformus*) and inconnu (*Stenodus leucichthys*) as both species use the delta's distributaries and open-ended sloughs for spawning purposes. Lowering of water levels may entirely restrict migration up the Slave River and greatly limit the number of open-ended sloughs for spawning habitat as water levels drop below the mouths of these old distributaries.

Lowering of water levels during the spring would impede the annual spring migration of northern pike (*Esox lucius*) and burbot (*Lota lota*) to similar spawning habitat used by the whitefish

and inconnu during the fall. Delay of ice breakup would have harmful effects upon the northern pike because it spawns immediately after breakup. Lowering of the river levels during these periods of the year may seriously deplete the stock of these economically important fish.

6.5 Long-term environmental implications

6.5.1 Introduction

This section focuses on the probable long term downstream effects of large dam construction on the Slave River.

6.5.2 Discharge

Regulation will curtail the natural extremes of discharge in the Slave River (Figure 6.1), around which the ecology of its delta has evolved.

The spring flood will become a product of plant operating strategy. Depletion of water in the reservoir because of winter energy demand will result in a major portion of the spring flood being used to refill the reservoir. Only the inflow above that required to maintain economically efficient power production will be released downstream. Historical spring discharge levels of 6,234.8 m^3/s (June mean discharge for all recorded years) will undoubtedly drop below the reservoir.

The reduction of high spring discharge levels would end the annual flooding that the outer delta now experiences (section 4.1). The normal intermittent flooding of the mid delta and apex zones would no longer occur, and even rare floods which inundated

these areas in the past (1935 for example) would no longer take place. The ecological effects of flood loss would be a rapid maturing of the delta's successional ecosystems and a marked reduction in wildlife habitat.

6.5.3 Sediment loss

One of the most important and immediate effects of river impoundment would be the loss of bedload and coarse fraction of the suspended sediment by settling out in the reservoir. The deposition of sediment in hydroelectric reservoirs can range from 95 to 100% of the available load (Day, 1971). The sediments presently deposited in the Slave Delta range mostly between 2ϕ and 4.25ϕ, or fine sands and coarse silts. Fine silt and clay make up less than 4% of the sediment. This means that the larger sediment fractions which are presently responsible for the continued progradation and aggradation of the delta would be lost to the reservoir. The formation of topset beds, submarine levees and wavebuilt shoals depends upon the continued input of this sediment, and its loss would largely curtail the future growth of the delta.

The increased erosive capacity of the water discharging from the dam would enable the Slave River to regain some sediment between the dam and the delta. However, the amount would be much less than the average daily sediment transport of approximately 60000 tonnes presently being transported by the Slave River at Fort Fitzgerald, above the proposed dam site (Water Survey of Canada, 1977).

6.5.4 Channel degradation

Maddock (1976) argues that elimination of the spring flood decreases the width and increases the slope of a floodplain channel while encouraging the encroachment of riparian vegetation along the littoral zone of the old channel. On the other hand, he states that under some conditions, the elimination of sediment transported downstream promotes bank erosion, thereby increasing the width of the channel and reducing its slope. Rains (Pers. Comm., 1978) agrees with this last statement, but adds that the channel slope immediately below the dam would be reduced. As load contributed from this source increases downstream, the erosional effects would become less significant. The zone of relatively minor erosion would include the delta area until a post-dam equilibrium is reached.

The rather low frequency with which a large portion of the delta experiences flooding suggests that a general widening of the channels and reduction in slope would occur. This would result in greater erosion of levees and elimination of much littoral emergent vegetation. Sandbar and point bar development would be retarded as the bedload was greatly reduced.

6.5.5 Microclimate

Sprague (1972) and Gill (1973a, 1974) document the warming effect of spring breakup on the bioclimate of the Mackenzie Delta. Reduction of the spring flood levels and sediment loss would delay breakup in the delta prolonging the length of winter conditions and effectively reducing productivity.

6.6 Long-term ecological effects of river regulation

The lowering of water levels and reduction of alluviation in the interlevee depressions would allow successional vegetation to invade and displace the highly productive emergent growth. Willow species would rapidly invade these marshes and displace the now dominant shade intolerant *Equisetum fluviatile*. Similar successional trends would occur on seasonally ponded sloughs throughout much of the delta.

Elimination of flooding would allow white spruce to successfully germinate on the mid delta and eventually portions of the outer delta. Invasion of bryophyte species such as *Hylocomnium splendens* would occur and after a period of time the mid delta zone would resemble the present vegetation composition of the apex zone.

6.7 Study critique

Another spring and summer of fieldwork would have resulted in a more accurate vegetation map. A field season dispersed evenly throughout the year would have yielded a more holistic discussion of the complete environmental and ecological cycle.

Lichens were not sampled during the field season, as the author and field assistants were unfamiliar with the ecology and identification of these plants. A detailed examination of bryophyte distribution on the delta was not accomplished as the bryophyte layer was only sampled in certain plots. The limitations of the Braun-Blanquet method of plant analysis are recognized by the author and are discussed by Muellor-Dombois and Ellenberg (1974).

Appendix 1

VASCULAR PLANTS

SELAGINELLACEAE

Selaginella selaginoides (L.) Link

EQUISETACEAE

Equisetum arvense L.
Equisetum hiemale L. var. *californicum*
Equisetum fluviatile L.
Equisetum palustre L.

PINACEAE

Picea glauca (Moench) Voss

TYPHACEAE

Typha latifolia L.

SPARGANIACEAE

Sparganium eurycarpum Engelm.
Sparganium multipedunculatum (Morong) Rydb.

POTAMOGETONACEAE

Potamogeton gramineus L.
Potamogeton praelongus Wulf.
Potamogeton perfoliatus L. subsp. *Richardsonii* (Bennett) Hult.
Potamogeton zosterifolius Schum. subsp. *zosteriformis* (Fern.) Hult.
Potamogeton vaginatus Turcz.

JUNCACINACEAE

Triglochin maritima L.

ALISMACEAE

Alisma plantago-aquatica L.
Sagittaria cuneata Sheld.

GRAMINEAE

Cinna latifolia (Trev.) Griseb.
Calamagrostis canadensis (Michx.) Beauv. subsp. *canadensis*
Calamagrostis canadensis (Michx.) Beauv. subsp. *Langsdorffi* (Link) Hult.
Beckmannia syzigachne (Steud.) Fern.
Poa pratensis L.
Glyceria borealis (Nash) Batchelder

Glyceria pauciflora Presl
Glyceria maxima (Hartm.) Holmb. subsp. *grandis* (S.Wats.) Hult.
Agropyron pauciflorum (Schwein.) Hitchc. subsp. *pauciflorum*
Agropyron trachycaulum (Link) Malte

CYPERACEAE

Eriophorum angustifolium Honck. subsp. *subarcticum* (Vassiljev) Hult.
Eriophorum gracile W.D.J. Koch
Scirpus validus M. Vahl.
Scirpus microcarpus Presl
Eleocharis palustris (L.) Roem & Schult.
Carex diandra Schrank
Carex aquatilis Wahlenb. subsp. *aquatilis*
Carex media R. Br.
Carex rostrata Stokes
Carex atherodes Spreng.

LEMNACEAE

Lemna minor L.
Lemna trisulca L.

JUNCACEAE

Juncus alpinus Vill. *nodulosus* (Wahlenb.)

ORCHIDACEAE

Platanthera hyperborea (L.) Lindl.
Platanthera obtusata (Pursh) Lindl.

SALICACEAE

Populus balsamifera L. subsp. *balsamifera*
Populus tremuloides Michx.
Salix glauca L. subsp. *acutifolia* (Hook.) Hult.
Salix arbusculoides Anderss.
Salix interior Rowlee
Salix lasiandra Benth.
Salix planifolia Pursh.
Salix pseudomonticola Ball.

BETULACEAE

Alnus incana (L.) Moench subsp. *tenuifolia* (Nutt.) Breitong

SANTALACEAE

Geocaulon lividum (Richards.) Fern.

POLYGONACEAE

Rumex occidentalis S. Wats. var. *fenestratus* (Greene) LePage

CARYOPHYLLACEAE

Stellaria crassifolia Ehrh.
Stellaria longifolia Muhl.
Stellaria calycantha (Ledeb.) Bong subsp. *calycantha*
Stellaria calycantha (Ledeb.) Bong subsp. *interior* Hult.

NYMPHAEACEAE

Nuphar variegatum Engelm.

RANUNCULACEAE

Caltha palustris L. subsp. *arctica* (R.Br.) Hult.
Actea rubra (Ait.) Willd. subsp. *rubra*
Actea rubra (Ait.) Willd. subsp. *neglecta* (Gillman) Robins
Ranunculus hyperboreus Rottb. subsp. *hyperboreus*
Ranunculus sceleratus L. subsp. *multifidus* (Nutt.) Hult.
Ranunculus Macovnii Britt.

CRUCIFERAE

Rorippa islandica (Oeder) Borb. subsp. *islandica*

SAXIFRAGACENE

Parnassia palustris L. subsp. *neogaea* (Fern.) Hult.
Ribes lacustre (Pers.) Poir.
Ribes oxyacanthoides L.
Ribes hudsonianum Richards.
Ribes triste Pall
Ribes hirtellum Michx.

ROSACEAE
Rubus pubescens Ra F.
Rubus arcticus L. subsp. *Acaulis* (Michx.) Focke
Rubus idaeus L. subsp. *melanolasius* (Dieck) Focke
Fragaria virginiana Duchesne subsp. *glauca* (S.Wats.) Staudt
Potentilla palustris (L.) Scop.
Potentilla norvegica L. subsp. *monspeliensis* (L.)Aschers. & Graebn
Potentilla anserina L.

Geum macrophyllum Willd. subsp. *perincisum* (Rydb.) Hult.
Dryas integrifolia M.Vahl subsp. *integrifolia*
Rosa acicularis Lindl.
Rosa woodsii Lindl.

LEGUMINOSAE

Astragalus eucosmus Robins. subsp. *eucosmus*
Vicia americana Muhl.
Vicia sparsifolia Nutt.

ELAEAGNACEAE

Shepherdia canadensis (L.) Nutt.

ONAGRACEAE

Epilobium angustifolium L. subsp. *angustifolium*
Epilobium glandulosum Lehm.

HALORAGACEAE

Myriophyllum spicatum L. subsp. *exalbescens* (Fern.) Hult.
Hippuris vulgaris L.

UMBELLIFERAE

Cicuta mackenzieana Raup.
Sium suave Walt
Heracleum lanatum Michx.

CORNACEAE

Cornus stolonifera Michx.
Cornus canadensis L.

PYROLACEAE

Pyrola asarifolia Michx. var. *purpurea* (Bunge) Fern.
Pyrola grandiflora Radius
Pyrola minor L.
Pyrola secunda L. subsp. *secunda*
Pyrola secunda L. subsp. *obtusata* (Turcz.) Hult.
Moneses uniflora (L.) Gray

ERICACEAE

Arctostaphylos uva-ursi L. Spreng. var. *uva-ursi*

BORAGINACEAE

Mertensia paniculata (Ait.) G.Don var. *paniculata*

LABIATAE

Scutellaria galericulata L. var. *pubescens* Benth.

SCROPHULARIACEAE

Castilleja miniata Dougl.
Pedicularis labradorica Wirsing

LENTIBULARIACEAE

Utricularia vulgaris L. subsp. *macrorhiza* (LeConte) Clausen
Utricularia intermedia Hayne
Utricularia minor L.

PLANTAGINACEAE

Plantago canescens Adams
Plantago major L. var. *major*

RUBIACEAE

Galium triflorum Michx.
Galium trifidum L. subsp. *trifidum*

CAPRIGOLIACEAE

Viburnum edule (Michx.) Raf.
Linnaea borealis L. subsp. *americana* (Forbes) Hult.

COMPOSITAE

Aster sibiricus L.
Erigeron acris L. var. *asteroides* (Andrz. ex Bess.) DC.
Achillea sibirica Ledeb
Petasites palmatus (Ait.) Gray
Petasites sagittatus (Banks) Gray
Senecio congestus (R.Br.) DC.
Senecio pauperculus Michx.

MOSS

DITRICHACEAE

Ceratodon purpureus (Hedw.) Brid.

BRYACEAE

Leptobryum pyriforme (Hedw.) Wils.

AULACOMNIACEAE

Aulavcomnium palustre (Hedw.) Schwaeger

AMBLYSTEGIACEAE

Cratoneuron commutatum (Hedw.) Roth.
Campylium stellatum (Hedw.) Jens.
Amblystegium serpens (Hedw.) B.S.G.

BRACHYTHEICIACEAE

Homalothecium nitens (Hedw.) Robin

HYPNACEAE

Pylaisiella polyanthe B.S.G.

HYLOCOMIACEAE

Hylocomnium splendens (Hedw.) B.S.G.

ABLYSTEGIACEAE

Hygrohypnum montanum (Hedw.) B.S.G.

RICCIACEAE

Ricciocarpus natans (L.) Corda
Riccia fluitans L.

Vascular plants after Hulten (1974), Moss (1974) and Fassett (1975)

Moss after Grout (1972)

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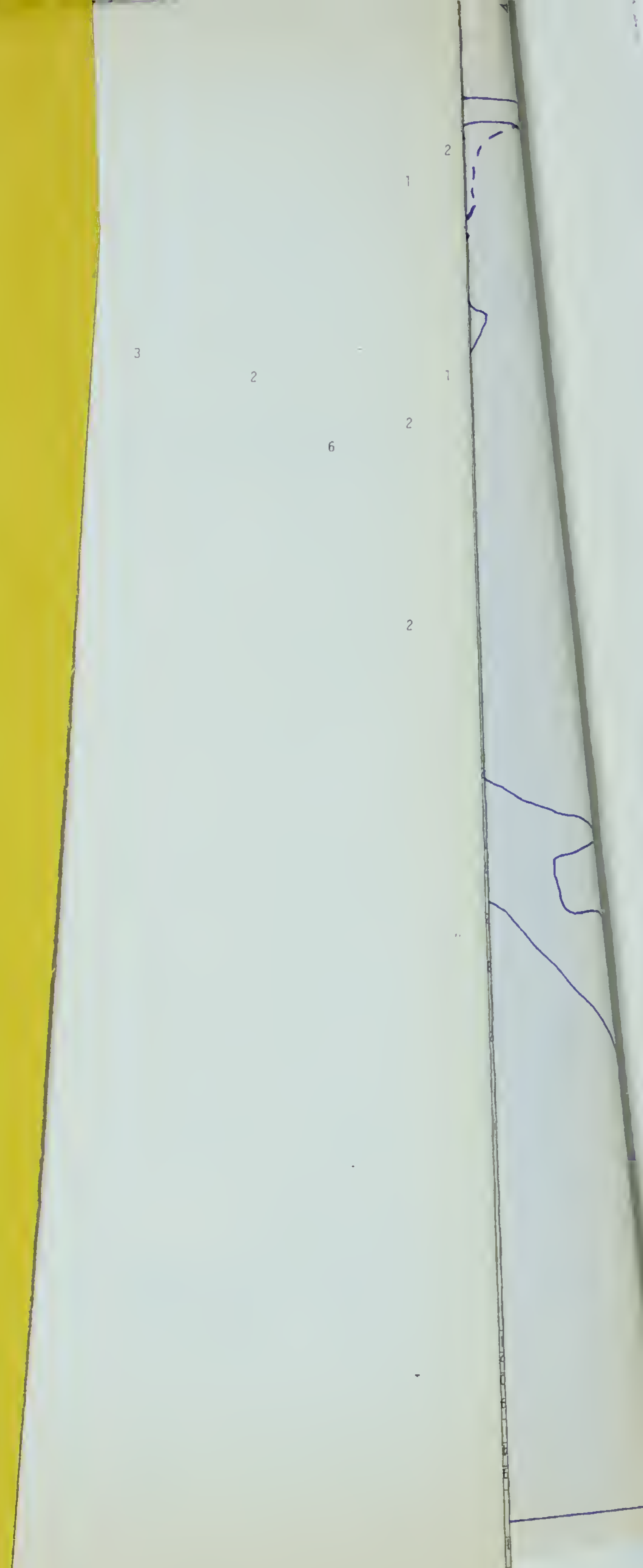
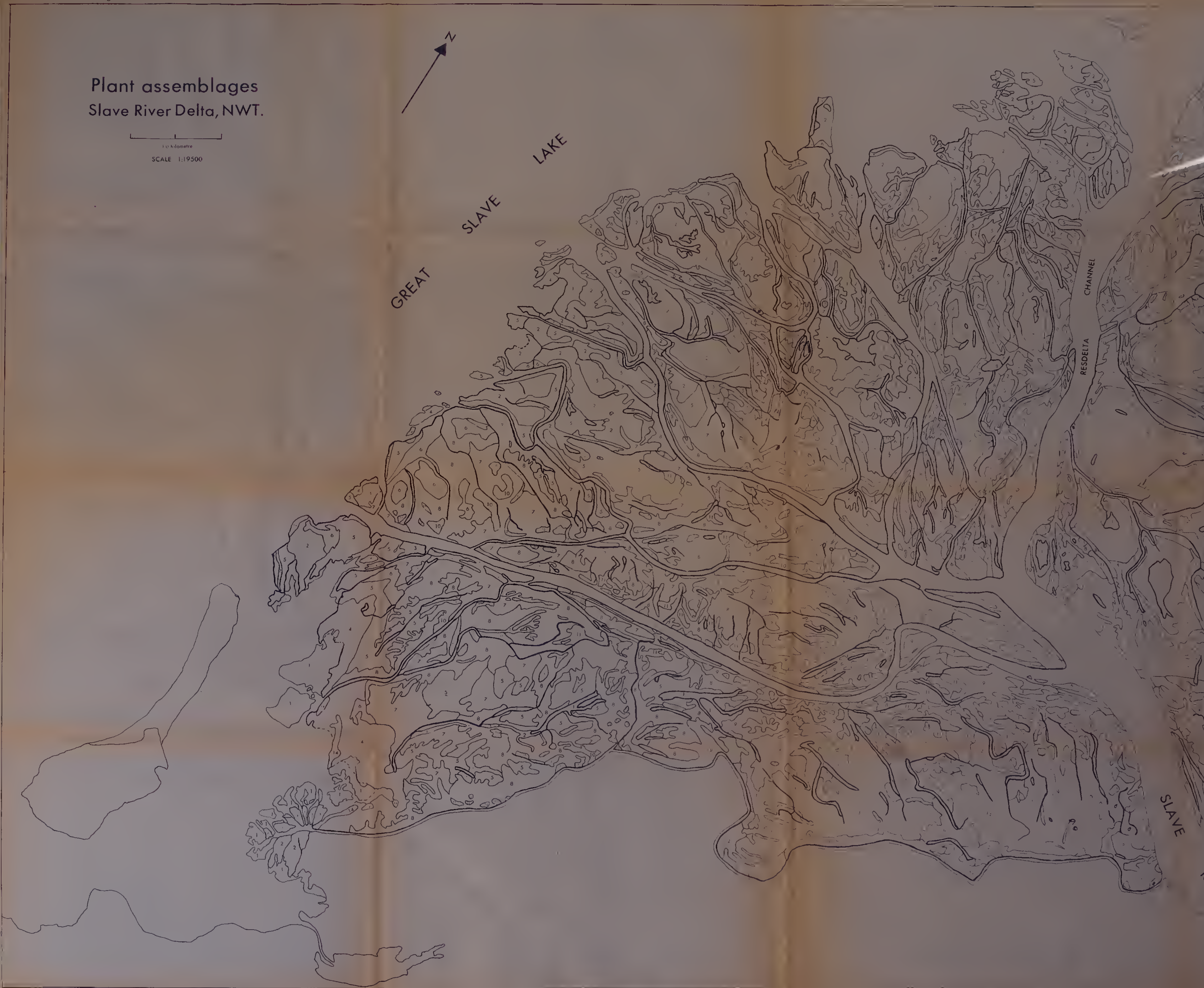


Flood frequency: 1.Annuall

Figure 5.1


Plant assemblages
Slave River Delta, NWT.
1.0 kilometre
SCALE 1:19500
N
GREAT SLAVE LAKE
RESDELTA CHANNEL
SLAVE RIVER

SLAVE LAKE
RESDELTA CHANNEL
SLAVE RIVER
Plant Assemblages
Aquatic
Equisetum
Carex
Equisetum-Carex
Salix-Equisetum
Salix
Salix-Alnus
Alnus-Salix
Alnus
Populus
Decadent Populus
Picea (successional stage)
Picea (climax)
Driftwood
Building

Table 5.1 Assemblages table

Flood frequency: 1.Annually, 2. Each 2-7 years, 3. Rarely